4400 OPERATOR MAN

PERKIN-ELMER

4400-SERIES OPERATOR'S MANUAL

THE PERKIN-ELMER CORPORATION
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Chapter 1

INTRODUCTION

1.1 4400-Series System Overview

The 4400-Series Production Sputtering Systems are manufactured in three (3) specific configurations, as follows:

MODEL 4400 — A manually-loaded system capable of limited automatic operation, but requiring manual selection of target and sputtering mode. The Model 4400 sputtering head is equipped with four (4) 8" round cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. (Mo shields, vane shutter, and full circle shutter.)

MODEL 4450 — A manually-loaded system capable of fully automatic operation. The Model 4450 sputtering head is equipped with three (3) Delta™ cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. Using optional adaptors, the cathode apertures can also accept 8" round targets. (Mo flame sprayed shields and shutters standard; W-C flame sprayed shields and shutters optional.)

MODEL 4480 — A cassette-to-cassette automatic wafer loading system capable of fully automatic operation. Capacity per pallet (in automatic wafer handling mode):

SIZE WAFERS	QTY. PER PALLET
3" (75mm)	16
4" (100mm)	12
5" (125mm)	8
6" (150mm)	7

The Model 4480 sputtering head is equipped with three (3) Delta™ cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. Using optional adaptors, the cathode apertures can also accept 8" round targets. (Mo flame sprayed shields and shutters standard; W-C flame sprayed shields and shutters optional.)

The Perkin-Elmer 4400-Series Production Sputtering Systems deposit a wide

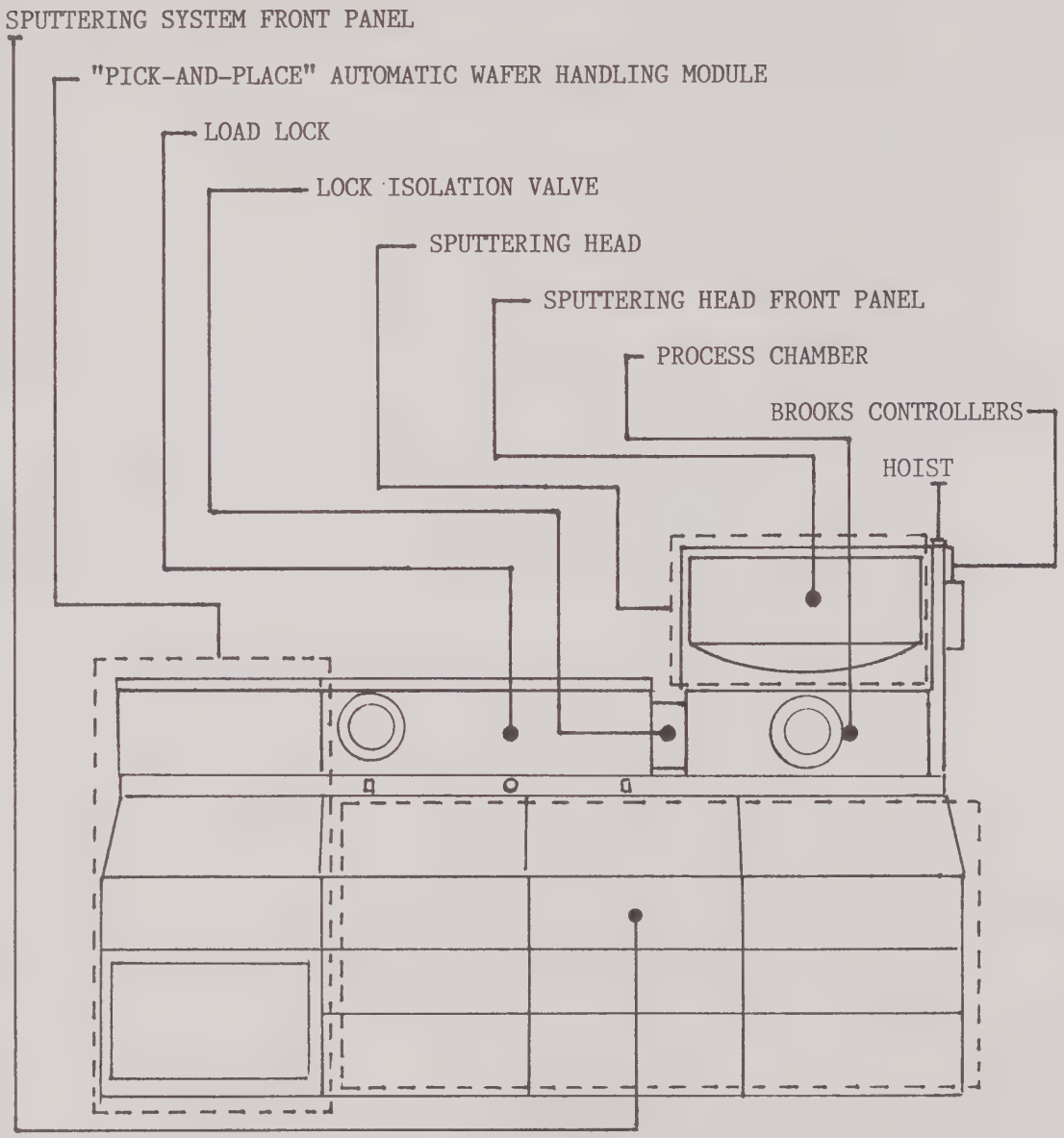


FIGURE 1-1

THE MODEL 4480 SPUTTERING SYSTEM (FRONT VIEW)

variety of materials onto substrates such as ceramics, metals, plastics, glass and semiconductors. The systems also can be used for RF sputter-etching, a process in which material is removed from, rather than being deposited on, the substrates prior to sputter deposition.

These sputtering systems sequentially deposit thin films of up to three different materials onto a single substrate, thus attaining sandwich-structured films such as multi-layer optical interference filters or semiconductor devices. Resulting thin films range in thickness from a few Angstroms up to several microns.

For improved throughput and added convenience, the high-capacity load lock permits substrate wafer loading without breaking vacuum in the process chamber. A microprocessor-based Main System Controller (MSC) provides complete automation of sputtering operations on Models 4450 and 4480 (target and mode selection are NOT automated on the Model 4400).

Table 1-1 compares the features of different 4400-Series systems.

TABLE 1-1
COMPARISON OF FEATURES

FEATURES	4400	4450	4480
4400-SYSTEM BASIC CONSOLE	STD.	STD.	STD.
MAIN SYSTEM CONTROLLER (MSC)	STD.	STD.	STD.
DGC-III ION TUBE CONTROLLER	STD.	STD.	STD.
DELTA™ CO-SPUT HEAD WITH FLAME SPRAYED SHIELDING	N/A	STD.	STD.
DELTA™ TARGETS	N/A	STD.	STD.
8" ROUND TARGETS	STD.	OPTION	OPTION
RF OR DC WITH RF BIAS	STD.	STD.	STD.
RF POWER SPLITTING	STD.	N/A	N/A
AUTOMATIC WAFER HANDLING	N/A	N/A	STD.
PE-6100 DATA TERMINAL	STD.	STD.	STD.
LOAD LOCK HI-VAC PUMP	OPTION	OPTION	STD.
PROCESS CHAMBER TURBO PUMP	OPTION	OPTION	OPTION
LOAD LOCK RADIANT HEAT	OPTION	OPTION	STD.
IN-PROCESS RADIANT HEAT	OPTION	OPTION	OPTION
BROOKS AUTOMATIC GAS CONTROL FOR 1, 2, OR 3 GASES	OPTION	OPTION	OPTION

STD = STANDARD OPTION = OPTIONAL N/A = NOT AVAILABLE

1.1.1 Description of Features

- High-rate DC magnetron sputtering (4450 and 4480 only). Aluminum and aluminum alloys can be sputter deposited at rates of up to 200 Angstroms per kilowatt-minute.

- Optimum use of processing equipment for maximum wafer efficiency and production rate.

- Maximum versatility to process a variety of products, applying the proper sputtering operation for each application.

- High vacuum to ensure contamination-free conditions for critical deposition processes (e.g., aluminum alloys, platinum).

- Specialized pallets for ease of substrate loading/unloading.

- "Drop-in" targets for quick target changes -- no screws to bother with.

- "Snap-out" deposition shields for quick, easy maintenance.

- Fail-safe system protection (e.g., water-flow switches to shut down system automatically in the event of cooling system failure, etc.)

- Additional safety features for operator and system protection (e.g., two-button initiation of pump-down and load sequences, interlocked equipment covers, etc.).

1.2 The Sputtering Process

Sputtering is a momentum transfer process in which atoms from a cathode/target are driven off (or "sputtered") by bombarding ions. In this process the momentum of the bombarding particles is more important than the energy. For example, a hydrogen or helium ion accelerated to 3,000 eV will cause very little sputtering compared to an ion of argon (which is chemically inert) with the same 3,000 eV energy, simply because the much lighter hydrogen or helium ion has much less momentum.

Sputtered atoms travel until they strike a substrate, where they are deposited to form the desired thin film. As individual atoms, they can be chemically active and form compounds with the ions and atoms of the bombarding gas. For this reason, inert argon typically is used as the bombarding gas. In some applications, however, a reactive gas is intentionally added to the argon to alter the chemical composition of the deposited film (e.g., nitrogen gas in combination with tantalum sputtering to form tantalum nitride, TaN).

When argon atoms strike the target, their electrical charge is neutralized and they return to the process as atoms. If the target is an insulator, the neutralization process results in a positive charge on the target surface. This charge may grow so large that the bombarding ions are repelled and the sputtering process stopped. To allow the process to continue, polarity of the target must be reversed, attracting enough electrons from the discharge to eliminate the surface charge. This periodic reversal of polarity is accomplished automatically by applying RF voltage to the target assembly (hence the term "RF sputtering").

Of interest here is the diode rectifier-like behavior of the target and discharge system. This results from the vast difference in mobilities of ions and electrons. Electrons, being so much faster, are attracted in greater numbers to the target during the positive half-period of the RF voltage than are ions during the negative half-period. Thus, the target develops a negative DC bias.

4400-Series Production Sputtering Systems perform a number of sputtering processes (described below), each of which is ideal for a different application.

1.2.1 RF Diode Sputter Deposition

When the vacuum set point is reached, sputtering gas (typically argon) is introduced into the process chamber at a pre-selected rate (typically 40 sccm). A plasma, or self-sustaining glow discharge, initiated by an automatic plasma igniter, appears when RF power is applied between the target and electrical ground, ionizing the argon gas.

A negative (-) potential applied to the target, as a result of the applied RF power, attracts the ionized argon at a momentum determined by a) the magnitude of the applied potential and b) the mass of the ion. The momentum

of the incoming argon ion is transferred to the target material, causing surface atoms or molecules of target material to be ejected (sputtered). These sputtered atoms travel across the gap separating the target (cathode) and substrate table (anode), and are deposited on the substrates (wafers) which are arranged on the substrate pallet.

1.2.2 RF Magnetron Sputter Deposition

RF magnetron and RF diode sputtering are very similar, except that during RF magnetron sputtering a magnetic field deflects the secondary electrons (which are produced during normal sputtering operation) away from the substrates. The sputtering process, which is cooler than RF diode sputtering, permits materials to be sputter deposited on substrates at lower temperatures and greatly reduces the chance of radiation damage to delicate substrates.

Because the impedence of a magnetron is lower, higher power densities are possible at lower potentials, effecting higher sputter rates.

1.2.3 DC Magnetron Sputter Deposition

DC magnetron targets enhance the plasma density and increase the sputtering rate, by trapping electrons in an electromagnetic "envelope." This "envelope" is formed when lines of the magnetic field enter and exit the target face and when the loci of maximum transverse magnetic fields form a closed figure. Because the currents involved are very large, a separate, positively-biased anode (a dark space shield) is used to collect the electrons. A similar dark space shield is used in RF diode and RF magnetron deposition. This dark space shield prevents the sides of the target and target backing plate from sputtering.

1.2.4 RF Sputter-Etching

Essentially the reverse process of RF diode sputter deposition, in which the substrate table becomes the cathode (negative pole) and the target assembly becomes the anode (positive pole). Under these circumstances, surface material from the substrates is ejected. Surface impurities are ejected along with substrate material, making this process useful for pre-cleaning substrates prior to sputter deposition. In order to prevent ejected material from contaminating the target, a shutter is positioned between target and substrate.

1.2.5 Bias Sputter Deposition

Bias sputtering combines the DC or RF sputtering and the RF etching operations. While DC or RF power is applied to the target, a small amount of RF is also applied to the substrate table. As a result, the substrate and target are both bombarded by ions (the substrate to a lesser extent than the target). In many applications this process yields superior quality films than can be attained using DC or RF sputtering with grounded substrates. Bias sputtering influences the crystal structure, and tends to re-sputter trapped argon from the growing film during deposition and rearrange individual atoms of the sputtered material; this improves stoichiometry and step coverage. Bias sputtering can be used to adjust film resistivity and

film stress to desired levels.

1.2.6 Reactive Sputtering

Some metals, such as nitrides and oxides, are best deposited by this method: the target is the parent metal and a small amount of nitrogen or oxygen is introduced into the process chamber along with the argon sputtering gas. Because ionized gases are typically highly reactive, a film deposited in a mixture of argon and a reactive gas will often form a compound with the reactive gas (e.g., a nitride or an oxide).

WARNING

IF OXYGEN IS TO FORM 7% OR MORE OF THE SPUTTERING GAS MIXTURE, SPECIAL PRECAUTIONS MUST BE TAKEN (E.G., USING SPECIAL MECHANICAL PUMP OILS [SUCH AS FOMBLIN] AND USING OXYGEN SERVICE PUMPS). CONSULT YOUR PERKIN-ELMER FIELD SERVICE REPRESENTATIVE.

1.2.7 Co-Deposition

Sometimes called co-sputtering or dual deposition, co-deposition is identical in principle and practice to other types of sputter deposition, except that two targets (typically of different materials) are simultaneously activated. Substrates passing sequentially and repeatedly beneath the targets are coated with alternating, very thin films of the two materials. Under certain circumstances, the resultant film can be equivalent to or better than one formed using a composite target. During co-deposition, both targets may be RF, both DC, or one RF and one DC.

1.2.8 Target Pre-Cleaning

RF or DC power is applied to the target to remove oxidation and accumulated foreign material. Oxidation occurs each time the system is vented to atmosphere, and is also present on newly installed targets. Pre-cleaning is also recommended prior to processing each batch of substrates when certain alloys are used. In order to prevent ejected material from contaminating the substrate table, a shutter is normally positioned between it and the target.

CAUTION

IN THE CASE OF DC MAGNETRON PRE-CLEANING, TEMPERATURES REACHED DURING TARGET PRE-CLEANING MAY BE SUFFICIENT TO WARP SHIELDS. FOLLOW PRE-CLEANING PROCEDURES GIVEN BELOW.

1.2.8.1 Pre-Cleaning a New Target

When pre-cleaning ("burning-in") a new target, especially aluminum, the target must slowly be brought up in power from about 2 kW to the full power of the power supply being used (5 kW or 10 kW). Pre-cleaning must continue until all evidence of arcing disappears, and target power and voltage are stabilized. THIS AMOUNT OF SPUTTERING WILL WARP A CLOSED SHUTTER. It is therefore recommended that pre-cleaning of a new target be done with the an empty pallet in the chamber, in the normal sputter mode (i.e., shutters

OPEN).

1.2.8.2 Pre-Cleaning a Contaminated Target

A target is considered to be contaminated if it has been exposed to atmosphere. Pre-cleaning a contaminated target consists of removing 500 - 1000 Angstroms of material from the target (the removed material is usually deposited onto closed shutters). IF MORE THAN 1000 ANGSTROMS OF MATERIAL IS TO BE REMOVED AT ONE TIME, THE PROCEDURE FOR PRE-CLEANING A NEW TARGET MUST BE FOLLOWED, TO PREVENT WARPING OF SHIELDS.

Use Table 1-2 as an approximate guideline for removing the desired thickness of material from your target.

TABLE 1-2

MAT'L	8" ROUND RF DIODE	8" ROUND DC MAGNETRON	DELTA RF DIODE	DELTA RF MAGNETRON	DELTA DC MAGNETRON
Ag	140	290			480
Al	40	120			200
Al2O3[3]	12			40	
Au	100	310			400
C		5			
Cr	35	110			180
CrNx	25	115			160
CrSi2	18	90			125
Cu	75	280	80		320
Mo	30	130			220
MoSi2	20	140			150
Ni[2]	40	150			
Nichrome	35	165			125
Pd	80	280			390
Perm-alloy[2]	30	150			
Pt	60	170			280
Quartz[3]	20		25	50	
Si[3]	20			90	
Si3N4[3]	10			30	
Ta	20	110			150
TaNx	20	100			140
Ti	30	110			140
TiNx	15	25			125
Ti/W(10%)	30	110			150
W	20	125			150
WNx		90			125
Zr	40				

Rates shown above are given in Angstroms/min/kW, and are typical only. Actual rates for any given system will depend upon process and system parameters. Rates are approximately linear with applied power except where otherwise indicated. The maximum power levels for 8-inch round targets are 5 kW DC/2 kW RF; for Delta™ targets 10 kW DC/3 kW RF. Some materials, due to their nature, are limited to power levels substantially less than the maximum power rating of each cathode type.

NOTES:

[1] Insufficient data available for most materials with RF Delta™ operation -- DC magnetron recommended for metals.
[2] Ferromagnetic materials -- magnetron mode is possible with thin targets only, but not recommended.
[3] Dielectric materials -- require the use of RF power. Rates are non-linear.

Chapter 2

MODEL 4400

2.1 OVERVIEW: Model 4400

FEATURES OF THE MODEL 4400

- MICROPROCESSOR MAIN SYSTEM CONTROLLER (MSC)
- SPUTTER HEAD ASSEMBLIES FOR UP TO FOUR (4) 8" ROUND CATHODES
- RF/RF POWER SPLITTING (OPTIONAL - DIODES ONLY)
- DGC-III ION GAUGE CONTROLLER
- BROOKS AUTOMATIC GAS CONTROL SYSTEM FOR 1, 2, OR 3 GASES (OPTIONAL)
- PERKIN-ELMER PE-6100 DATA TERMINAL
- LOAD LOCK HI-VAC PUMPING (OPTIONAL)
- LOAD LOCK 200 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- RF BIAS
- IN-PROCESS 350 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- SUBSTRATE TABLE INDEXING
- ULTRA-HIGH VACUUM COMPONENTS
- HYDROGEN GETTER PUMP (OPTIONAL)
- FULL FLOOD MEISSNER TRAP
- THREE (3) OPERATING MODES (WITH OR WITHOUT RF SUBSTRATE BIAS):
    * DC MAGNETRON
    * RF MAGNETRON
    * RF DIODE

The Model 4400, in a typical configuration, is controlled via the following: the Main System Controller (MSC), the Servo Match™ Controller, The DGC-III Digital Ion Gauge Controller, the Load Lock Turbomolecular Pump Frequency

Controller, the DC Magnetron Controller, the RF Power Supply and Power/Voltage Stabilizer, and the Precision Table Rotation Speed Control.

2.1.1 Main System Controller (MSC)

The MSC is the communication link between opeator and system. It controls, directly or indirectly, all process and substrate loading instruction sequences programmed by the operator.

The MSC may be used in the manual mode, by manipulating toggle switches, to control the operation of the pumps, valves, and mechanical assemblies. WHEN USED IN THE MANUAL MODE, THE MSC SAFETY INTERLOCK SYSTEM IS INACTIVE. THE MANUAL MODE IS FOR THE USE OF SERVICE PERSONNEL AND SYSTEM ENGINEERS ONLY.

For all routine production operations, the system is designed to be controlled from the MSC in the AUTOMATIC mode. In the automatic mode, the MSC can control any pre-programmed sequence of the following operations:

- Process Time (Deposition or Etch)
- DC and RF Power/Voltage ON/OFF
- DC and RF Power/Voltage Levels
- Process Gas ON/OFF
- Process Gas Flow Levels (Requires Brooks Automatic Gas Controller Option; otherwise, the throttle valve is pre-set at 40 sccm at 10 milliTorr)
- Process Gas Pressure (Requires Automatic Pressure Control Option, Included with the Brooks Gas Controller Option; otherwise, set via manually operated toggle-ON/OFF and micrometer flow regulating needle valves)
- Process Heat ON/OFF (Requires Process Heat Option)
- Automatic cryo pump regeneration
- Automatic Meissner trap fill cycles and regeneration
- Automatic pump down from atmosphere
- Load Lock Heat ON/OFF (Requires Load Lock Heat Option)
- Transfer of Substrate Pallet from Load Lock to Process Chamber and Back
- Substrate Table Height (in Process Chamber)

The following functions CANNOT be controlled from the system controller (i.e., they must be selected manually by the operator, using switches on the control panel of the sputter head assembly):

- Sputtering Mode SELECTION (i.e., RF Deposit, Bias Deposit, Etch, DC Deposit)

- Shutter Position

- Target Selection (TARGET NUMBER 1, 2, 3 OR 4)

During the process cycle, the computer monitors the process gas pressure and flow control system option (if installed). If any of the parameters associated with these subsystems varies unacceptably from programmed levels, the computer will halt the process and sound an alarm.

2.1.2 DGC-III Ion Gauge Controller

The Perkin-Elmer DGC-III controller monitors base pressure in both the process chamber and the load lock. Pressure set point values are programmed into the DGC-III front panel by the operator.

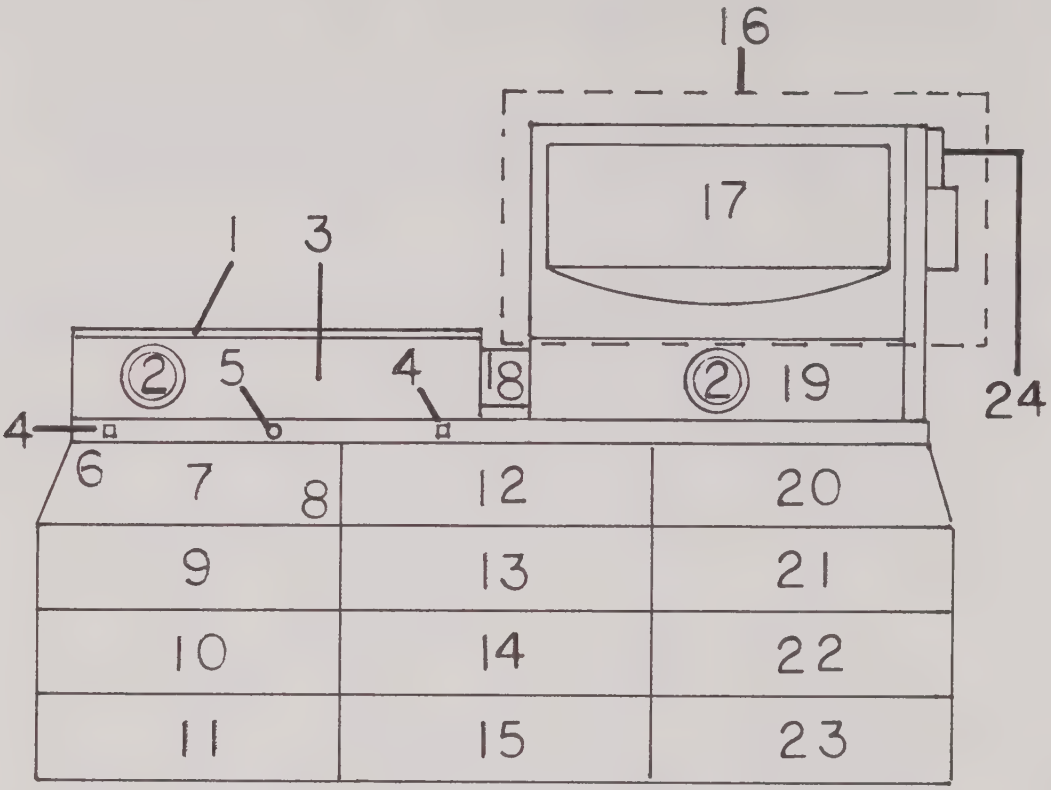


FIGURE 2-1

MODEL 4400 SYSTEM LAYOUT

1. LOAD LOCK LID
2. VIEW PORTS
3. LOAD LOCK
4. LID UP/DOWN SWITCHES
5. EMERGENCY STOP PUSHBUTTON
6. TARGET ELAPSED TIME INDICATOR
7. PRECISION TABLE ROTATION CONTROL
8. DGC-III ION GAUGE CONTROLLER
9. ION SWITCH PANEL
10. LOAD LOCK HEATER POWER SUPPLY
11. NOT USED AT THIS TIME
12. MSC (MAIN SYSTEM CONTROLLER)
13. PROCESS PRESSURE REGULATOR
14. L/L TURBO FREQUENCY CONTROLLER
15. WATER FLOW SWITCHES
16. 4400 SPUTTER HEAD ASSEMBLY
17. SPUTTER HEAD CONTROL PANEL
18. LOAD LOCK ISOLATION VALVE
19. PROCESS CHAMBER
20. DC MAGNETRON CONTROLLER
21. RF POWER/VOLTAGE STABILIZER
22. SERVO-MATCH CONTROLLER
23. PROCESS TURBO FREQUENCY CONTROL
24. IN-PROCESS HEATER POWER SUPPLY
25. BROOKS GAS FLOW CONTROLLERS

2.2 Model 4400 System Layout

Figure 2-1 shows a front view of the Perkin-Elmer Model 4400 Production Sputtering System. Each numbered item corresponds to a description, below.

Chapters 5, 6, and 7 contain detailed descriptions (and operating information where applicable) for all 4400-Series subsystems and controls.

2.2.1 Load Lock Lid Activator [ITEM No. 4]

The Load Lock Lid Activator is controlled by two UP/DOWN rocker switches located on the front surface of the load lock. The operator must simultaneously select the same function on each switch in order to move the load lock lid. The load lock lid is interlocked to the MSC, making it impossible to start a process sequence, pump the load lock or open the isolation valve (in the automatic mode only) without first closing the load lock lid.

2.2.2 Target Elapsed Time Indicator [ITEM No. 6]

The target timer is an optional device used to record the number of sputtering-hours (measured to the nearest 1/10 hour) accumulated on each target.

2.2.3 Precision Table Rotation Speed Control [ITEM No. 7]

The precision table rotation speed controller allows the operator to select a table rotation in the range 0 - 10 rpm. Adjustments are made via switches and potentiometers on the front panel of the table drive unit.

The precision table drive also allows the operator to index the pallet within the process chamber (at speeds up to 5 rpm), and to pre-set a desired number of table rotations (at rotation speeds up to 10 rpm).

2.2.4 Ionization Switch Panel [ITEM No. 9]

The ionization gauge switch panel turns ON and OFF the Bayerd Alpert ion gauge tubes automatically. If the system is NOT equipped with a load lock Hi-Vac pump, there are only two (2) ion gauge tubes, either of which may be selected from the DGC-III controller (see Chapter 5).

Systems equipped with a load lock Hi-Vac pump are also equipped with three (3) ion gauge tubes. The DGC-III only allows the operator to choose between two (2) tubes. A rocker switch mounted on the front panel of the ion gauge controller is used to overcome this limitation:

"1" OR "2" SELECTED FROM DGC-III	ROCKER SWITCH POSITION	ION GAUGE TUBE SELECTED
1	N/A	LOAD LOCK
2	RIGHT SIDE IN	PROCESS CHAMBER
2	LEFT SIDE IN	PROCESS CHAMBER CRYO PUMP STACK

NOTE: THE DGC-III I/T BUTTON IS USED TO TOGGLE BETWEEN ION GAUGES AND THERMISTORS. THE SETTINGS DESCRIBED ABOVE APPLY ONLY WHEN ION GAUGES ARE SELECTED.

2.2.5 Load Lock Heater Power Supply [ITEM No. 10]

OPTION

The optional load lock heater elements are powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO ON/OFF control via the MSC.

OFF OFF.

ON ON VIA MANUAL CONTROL (OVERRIDES MSC).

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 5 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 200 degrees Centigrade is acheived after five (5) minutes.

2.2.6 Process Pressure Regulator [ITEM No. 13]

OPTION

Included as part of the automatic gas option (with the Brooks controller[s]), the process pressure regulator is used a) to servo-control the throttle valve automatically in order to maintain a pre-set pressure level (at a selected gas flow rate) in the process chamber, or b) (in the MANUAL mode) to switch-select one of two throttle valve positions: 100% open or closed to a position which maintains chamber pressure at 10 milliTorr with a 40sccm gas flow.

2.2.7 Load Lock Turbo Pump Frequency Controller [ITEM No. 14]

OPTION

Turbomolecular pump(s) reach operating speeds of about 35,000 rpm and must be slowly ramped up to speed. The turbo pump frequency controller automatically performs this function by multiplying the line frequency at a controlled rate to acheive the desired RPM. A meter on the front panel of this controller indicates the range of turbo speed.

A switch point at 80% of full speed is used to interlock the high vacuum valve.

2.2.8 Water Flow Switches [ITEM No. 15]

Water flow switches are placed in series with the cooling system water lines, and maintain an OPEN switch position as long as water continues to flow through the switch. Interruption of water flow or switch failure causes the switch to CLOSE, which is interpretted by the MSC as a hard error (i.e., an error which aborts the process). Each flow switch is factory pre-set for the specific minimum flow rate recommended for the device being cooled (see service manual for further details).

2.2.9 DC Magnetron Control [ITEM No. 20]

OPTION

Regulates the output power of the 5 or 10 kW DC power supply to a constant volt-amp (VA) product.

2.2.10 RF Power/Voltage Stabilizer [ITEM No. 21]

OPTION

Maintains constant power or voltage for RF sputtering despite considerable variations in AC line voltage, gas pressure, work characteristics, and temperature. Selecting POWER maintains pre-set power while varying the voltage. Selecting VOLTAGE maintains pre-set voltage while varying the power.

2.2.11 Servo Match™ Panel [ITEM No. 22]

OPTION

Automatically servos the RF tuning and load circuits located in the sputter head assembly, adjusting the circuits for minimum reflected power and the load circuit to compensate for the impedence of a target, or selection of a different gas or power level.

2.2.12 Process Chamber Turbo Pump Frequency Controller [ITEM No. 23]

OPTION

Same as Load Lock Turbo Frequency Controller (ITEM No. 14, above).

2.2.13 In-Process Heater Power Supply [ITEM No. 24]

OPTION

The in-process heater element is powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON.

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 8 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 350 degrees Centigrade is acheived after five (5) minutes.

2.2.14 Brooks Automatic Gas Controllers [ITEM No. 25]

OPTION

Independent flow levels of one to three gases are controlled by optional Brooks gas flow controllers. Both process gas pressure and individual gas flow levels are independently programmed via the MSC. Gas flow levels are conveniently displayed on the PE-6100 Data Terminal in sccm (Standard Cubic Centimeters per Minute).

Chapter 3

MODEL 4450

3.1 OVERVIEW: Model 4450

FEATURES OF THE MODEL 4450

- MICROPROCESSOR MAIN SYSTEM CONTROLLER (MSC)
- CO-DEPOSIT DELTA^{TM} CATHODE SPUTTER HEAD ASSEMBLY
- DGC-III ION GAUGE CONTROLLER
- BROOKS AUTOMATIC GAS CONTROL SYSTEM FOR 1, 2, OR 3 GASES (OPTIONAL)
- PERKIN-ELMER PE-6100 DATA TERMINAL
- LOAD LOCK HI-VAC PUMPING (OPTIONAL)
- LOAD LOCK 200 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- RF BIAS
- IN-PROCESS 350 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- SUBSTRATE TABLE INDEXING
- ULTRA-HIGH VACUUM COMPONENTS
- FULL FLOOD MEISSNER TRAP
- THREE (3) OPERATING MODES (WITH OR WITHOUT RF SUBSTRATE BIAS):
  * DC MAGNETRON
  * RF MAGNETRON
  * RF DIODE
- DELTA^{TM} HIGH RATE CATHODES

A typical Model 4450 system is controlled via the following controllers: the Main System Controller (MSC), the Servo Match^{TM} Controller, The DGC-III Ion Gauge Controller, Brooks Automatic Gas Controllers (optional), the Process Pressure Regulator (included with the Brooks option), the Load Lock Turbomolecular Pump Frequency Controller, the DC Magnetron Controller, the RF

Power/Voltage Stabilizer, the Three Target Timer (optional), the Precision Table Drive, the In-Process Heater Power Supply (optional), and the Load Lock Heater Power Supply (optional).

3.1.1 Main System Controller (MSC)

The MSC is the communication link between operator and system. It controls, directly or indirectly, all process and substrate loading instruction sequences programmed by the operator.

The MSC may be used in the manual mode, by manipulating toggle switches, to control the operation of the pumps, valves, and mechanical assemblies. WHEN USED IN THE MANUAL MODE, THE MSC SAFETY INTERLOCK SYSTEM IS INACTIVE. THE MANUAL MODE IS FOR THE USE OF SERVICE PERSONNEL AND SYSTEM ENGINEERS ONLY.

For all routine production operations, the system is designed to be controlled from the MSC in the AUTOMATIC mode. In the automatic mode, the MSC can control any pre-programmed sequence of the following operations:

- Process Time (Deposition or Etch)
- DC and RF Power ON/OFF
- DC and RF Power Levels
- Process Gas ON/OFF
- Process Gas Flow Levels (Requires Brooks Automatic Gas Controller Option; otherwise, the throttle valve is pre-set at 40 sccm at 10 milliTorr)
- Process Gas Pressure (Requires Automatic Pressure Control Option, Included with the Brooks Gas Controller Option; otherwise, set via manually operated toggle-ON/OFF and micrometer flow regulating needle valves)
- Process Heat ON/OFF (Requires Process Heat Option)
- Automatic cryo pump regeneration
- Automatic Meissner trap fill cycles and regeneration
- Automatic pump down from atmosphere
- Load Lock Heat ON/OFF (Requires Load Lock Heat Option)
- Transfer of Substrate Pallet from Load Lock to Process Chamber and Back
- Substrate Table Height (in Process Chamber)

During the process cycle, the computer monitors the process gas pressure and flow control system option (if installed). If any of the parameters associated with these subsystems varies unacceptably from programmed levels, the computer will halt the process and sound an alarm.

3.1.2 DGC-III Ion Gauge Controller

The Perkin-Elmer DGC-III controller monitors base pressure in both the process chamber and the load lock. Pressure set point values are programmed into the DGC-III front panel by the operator.

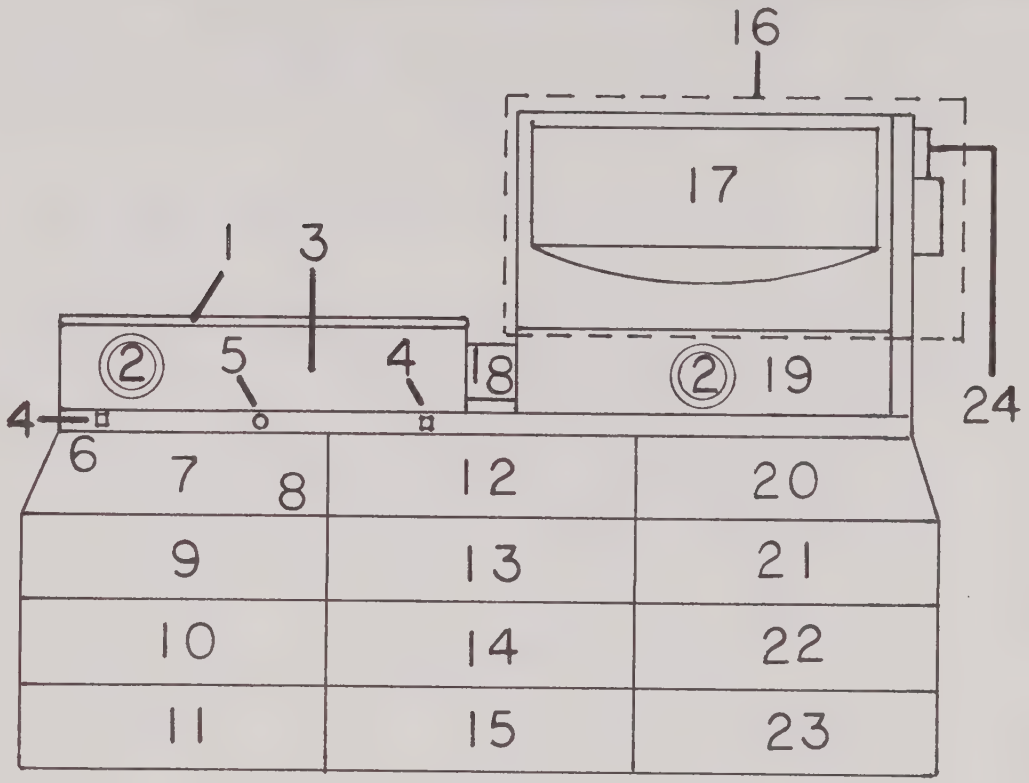


FIGURE 3-1

MODEL 4450 SYSTEM LAYOUT

1. LOAD LOCK LID
2. VIEW PORTS
3. LOAD LOCK
4. LID UP/DOWN SWITCHES
5. EMERGENCY STOP PUSHBUTTON
6. TARGET ELAPSED TIME INDICATOR
7. PRECISION TABLE ROTATION CONTROL
8. DGC-III ION GAUGE CONTROLLER
9. ION SWITCH PANEL
10. LOAD LOCK HEATER POWER SUPPLY
11. NOT USED AT THIS TIME
12. MSC (MAIN SYSTEM CONTROLLER)
13. PROCESS PRESSURE REGULATOR
14. L/L TURBO FREQUENCY CONTROLLER
15. WATER FLOW SWITCHES
16. 4450 SPUTTER HEAD ASSEMBLY
17. SPUTTER HEAD CONTROL PANEL
18. LOAD LOCK ISOLATION VALVE
19. PROCESS CHAMBER
20. DC MAGNETRON CONTROLLER
21. RF POWER/VOLTAGE STABILIZER
22. SERVO-MATCH CONTROLLER
23. PROCESS TURBO FREQUENCY CONTROL
24. IN-PROCESS HEATER POWER SUPPLY
25. BROOKS GAS FLOW CONTROLLERS

3.2 Model 4450 System Layout

Figure 2-1 shows a front view of the Perkin-Elmer Model 4450 Production Sputtering System. Each numbered item corresponds to a description, below.

Chapters 5, 6, and 7 contain detailed descriptions (and operating information where applicable) for all 4400-Series subsystems and controls.

3.2.1 Load Lock Lid Activator [ITEM No. 4]

The Load Lock Lid Activator is controlled by two UP/DOWN rocker switches located on the front surface of the load lock. The operator must simultaneously select the same function on each switch in order to move the load lock lid. The load lock lid is interlocked to the MSC, making it impossible to start a process sequence, pump the load lock or open the isolation valve (in the automatic mode only) without first closing the load lock lid.

3.2.2 Target Elapsed Time Indicator [ITEM No. 6]

The target timer is an optional device used to record the number of sputtering-hours (measured to the nearest 1/10 hour) accumulated on each target.

3.2.3 Precision Table Rotation Speed Control [ITEM No. 7]

The precision table rotation speed controller allows the operator to select a table rotation in the range 0 - 10 rpm. Adjustments are made via switches and potentiometers on the front panel of the table drive unit.

The precision table drive also allows the operator to index the pallet within the process chamber (at speeds up to 5 rpm), and to pre-set a desired number of table rotations (at rotation speeds up to 10 rpm).

3.2.4 Ionization Switch Panel [ITEM No. 9]

The ionization gauge switch panel turns ON and OFF the Bayerd Alpert ion gauge tubes automatically. If the system is NOT equipped with a load lock Hi-Vac pump, there are only two (2) ion gauge tubes, either of which may be selected from the DGC-III controller (see Chapter 5).

Systems equipped with a load lock Hi-Vac pump are also equipped with three (3) ion gauge tubes. The DGC-III only allows the operator to choose between two (2) tubes. A rocker switch mounted on the front panel of the ion gauge controller is used to overcome this limitation:

"1" OR "2" SELECTED FROM DGC-III	ROCKER SWITCH POSITION	ION GAUGE TUBE SELECTED
1	N/A	LOAD LOCK
2	RIGHT SIDE IN	PROCESS CHAMBER
2	LEFT SIDE IN	PROCESS CHAMBER CRYO PUMP STACK

NOTE: THE DGC-III I/T BUTTON IS USED TO TOGGLE BETWEEN ION GAUGES AND THERMISTORS. THE SETTINGS DESCRIBED ABOVE APPLY ONLY WHEN ION GAUGES ARE SELECTED.

3.2.5 Load Lock Heater Power Supply [ITEM No. 10]

OPTION

The optional load lock heater elements are powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON VIA MANUAL CONTROL (OVERRIDES MSC).

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 5 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 200 degrees Centigrade is acheived after five (5) minutes.

3.2.6 Process Pressure Regulator [ITEM No. 13]

OPTION

Included as part of the automatic gas option (with the Brooks controller[s]), the process pressure regulator is used a) to servo-control the throttle valve automatically in order to maintain a pre-set pressure level (at a selected gas flow rate) in the process chamber, or b) (in the MANUAL mode) to switch-select one of two throttle valve positions: 100% open or closed to a position which maintains chamber pressure at 10 milliTorr with a 40sccm gas flow.

3.2.7 Load Lock Turbo Pump Frequency Controller [ITEM No. 14]

OPTION

Turbomolecular pump(s) reach operating speeds of about 35,000 rpm and must be slowly ramped up to speed. The turbo pump frequency controller automatically performs this function by multiplying the line frequency at a controlled rate to acheive the desired RPM. A meter on the front panel of this controller indicates the range of turbo speed.

A switch point at 80% of full speed is used to interlock the high vacuum valve.

3.2.8 Process Chamber Turbo Pump Frequency Controller [ITEM No. 23]

OPTION

Same as 2.2.10, above.

3.2.9 Water Flow Switches [ITEM No. 15]

Water flow switches are placed in series with the cooling system water lines, and maintain an OPEN switch position as long as water continues to flow through the switch. Interruption of water flow or switch failure causes the switch to CLOSE, which is interpretted by the MSC as a hard error (i.e., an error which aborts the process). Each flow switch is factory pre-set for the specific minimum flow rate recommended for the device being cooled (see service manual for further details).

3.2.10 DC Magnetron Control [ITEM No. 20]

OPTION

Regulates the output power of the 5 or 10 kW DC power supply to a constant volt-amp (VA) product.

3.2.11 RF Power/Voltage Stabilizer [ITEM No. 21]

OPTION

Maintains constant power or voltage for RF sputtering despite considerable variations in AC line voltage, gas pressure, work characteristics, and temperature. Selecting POWER maintains pre-set power while varying the voltage. Selecting VOLTAGE maintains pre-set voltage while varying the power.

3.2.12 Servo Match™ Panel [ITEM No. 22]

OPTION

Automatically servos the RF tuning and load circuits located in the sputter head assembly, adjusting the circuits for minimum reflected power and the load circuit to compensate for the impedence of a target, or selection of a different gas or power level.

3.2.13 In-Process Heater Power Supply [ITEM No. 24]

OPTION

The in-process heater element is powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON.

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 8 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 350 degrees Centigrade is acheived after five (5) minutes.

3.2.14 Brooks Automatic Gas Controllers [ITEM No. 25]

OPTION

Independent flow levels of one to three gases are controlled by optional Brooks gas flow controllers. Both process gas pressure and individual gas flow levels are independently programmed via the MSC. Gas flow levels are conveniently displayed on the PE-6100 Data Terminal in sccm (Standard Cubic Centimeters per Minute).

Chapter 4

MODEL 4480

4.1 OVERVIEW: Model 4480

The Model 4480 is the most advanced model in the Perkin-Elmer 4400-Series of production sputtering systems.

ADVANCED FEATURES OF THE MODEL 4480

- CASSETTE-TO-CASSETTE OPERATION FOR 3" (75MM), 4" (100MM), 5" (125MM), OR 6" (150MM) WAFERS
- MICROPROCESSOR MAIN SYSTEM CONTROLLER (MSC)
- CO-DEPOSIT DELTA^{TM} CATHODE SPUTTER HEAD ASSEMBLY
- DGC-III ION GAUGE CONTROLLER
- BROOKS AUTOMATIC GAS CONTROL SYSTEM FOR 1, 2, OR 3 GASES (OPTIONAL)
- PERKIN-ELMER PE-6100 DATA TERMINAL
- LOAD LOCK HI-VAC PUMPING
- LOAD LOCK 200 DEGREE CENTIGRADE RADIANT HEATER
- RF BIAS
- IN-PROCESS 350 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- SUBSTRATE TABLE INDEXING
- ULTRA-HIGH VACUUM COMPONENTS
- FULL FLOOD MEISSNER TRAP
- THREE (3) OPERATING MODES (WITH OR WITHOUT RF SUBSTRATE BIAS):
    * DC MAGNETRON
    * RF MAGNETRON
    * RF DIODE
- DELTA^{TM} HIGH RATE CATHODES

A typical Model 4480 system is controlled via the following controllers: the Main System Controller (MSC), the Pick-and-Place Computer, the Servo Match™ Controller, The DGC-III Ion Gauge Controller, Brooks Automatic Gas Controllers (optional), the Process Pressure Regulator (included with the Brooks option), the Load Lock Turbomolecular Pump Frequency Controller, the DC Magnetron Controller, the RF Power/Voltage Stabilizer, the Three Target Timer (optional), the Precision Table Drive, the In-Process Heater Power Supply (optional), and the Load Lock Heater Power Supply.

4.1.1 Main System Controller (MSC)

The MSC is the communication link between operator and system. It controls, directly or indirectly, all process and substrate loading instruction sequences programmed by the operator.

The MSC may be used in the manual mode, by manipulating toggle switches, to control the operation of the pumps, valves, and mechanical assemblies. WHEN USED IN THE MANUAL MODE, THE MSC SAFETY INTERLOCK SYSTEM IS INACTIVE. THE MANUAL MODE IS FOR THE USE OF SERVICE PERSONNEL AND SYSTEM ENGINEERS ONLY.

For all routine production operations, the system is designed to be controlled from the MSC in the AUTOMATIC mode. In the automatic mode, the MSC can control any pre-programmed sequence of the following operations:

- Process Time (Deposition or Etch)
- DC and RF Power/Voltage ON/OFF
- DC and RF Power/Voltage Levels
- Process Gas ON/OFF
- Process Gas Flow Levels (Requires Brooks Automatic Gas Controller Option; otherwise, the throttle valve is pre-set at 40 sccm at 10 milliTorr)
- Process Gas Pressure (Requires Automatic Pressure Control Option, Included with the Brooks Gas Controller Option; otherwise, set via manually operated toggle-ON/OFF and micrometer flow regulating needle valves)
- Process Heat ON/OFF (Requires Process Heat Option)
- Automatic cryo pump regeneration
- Automatic Meissner trap fill cycles and regeneration
- Automatic pump down from atmosphere
- Load Lock Heat ON/OFF (Requires Load Lock Heat Option)
- Transfer of Substrate Pallet from Load Lock to Process Chamber and Back
- Substrate Table Height (in Process Chamber)

During the process cycle, the computer monitors the process gas pressure and flow control system. If any of the parameters associated with these subsystems varies unacceptably from pre-programmed levels, the computer will halt the process and sound an alarm.

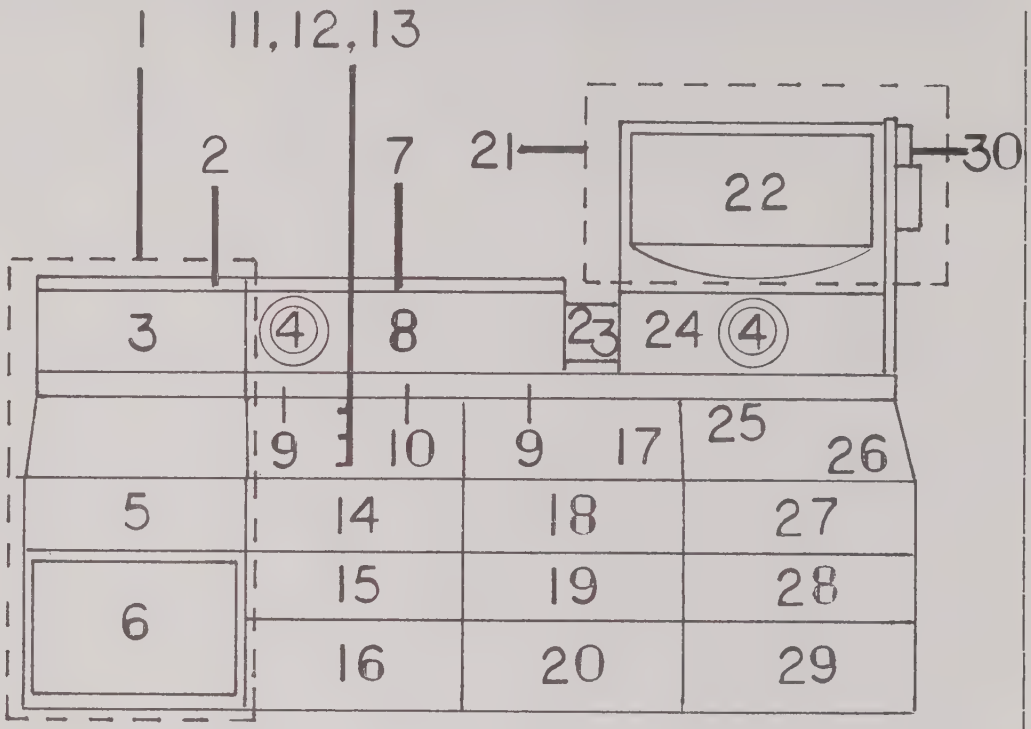


FIGURE 4-1

MODEL 4480 SYSTEM LAYOUT

1. "PICK-AND-PLACE" MODULE
2. CASSETTE CHAMBER LID
3. CASSETTE CHAMBER
4. VIEW PORTS
5. LID ACTIVATOR
6. "PICK-AND-PLACE" COMPUTER
7. LOAD LOCK LID
8. LOAD LOCK
9. LOAD LOCK LID UP/DOWN SWITCHES
10. EMERGENCY STOP PUSHBUTTON
11. TARGET ELAPSED TIME INDICATOR
12. PRECISION TABLE ROTATION CONTROL
13. DGC-III ION GAUGE CONTROLLER
14. ION SWITCH PANEL
15. LOAD LOCK HEATER POWER SUPPLY
16. NOT USED AT THIS TIME
17. MSC (MAIN SYSTEM CONTROLLER)
18. PROCESS PRESSURE REGULATOR
19. L/L TURBO FREQUENCY CONTROLLER
20. WATER FLOW SWITCHES
21. 4480 SPUTTER HEAD ASSEMBLY
22. SPUTTER HEAD CONTROL PANEL
23. LOAD LOCK ISOLATION VALVE
24. PROCESS CHAMBER
25. DC MAGNETRON CONTROLLER
26. RF POWER/VOLTAGE STABILIZER
27. SERVO-MATCH CONTROLLER
28. PROCESS TURBO FREQUENCY CONTROL
29. IN-PROCESS HEATER POWER SUPPLY
30. BROOKS GAS FLOW CONTROLLERS

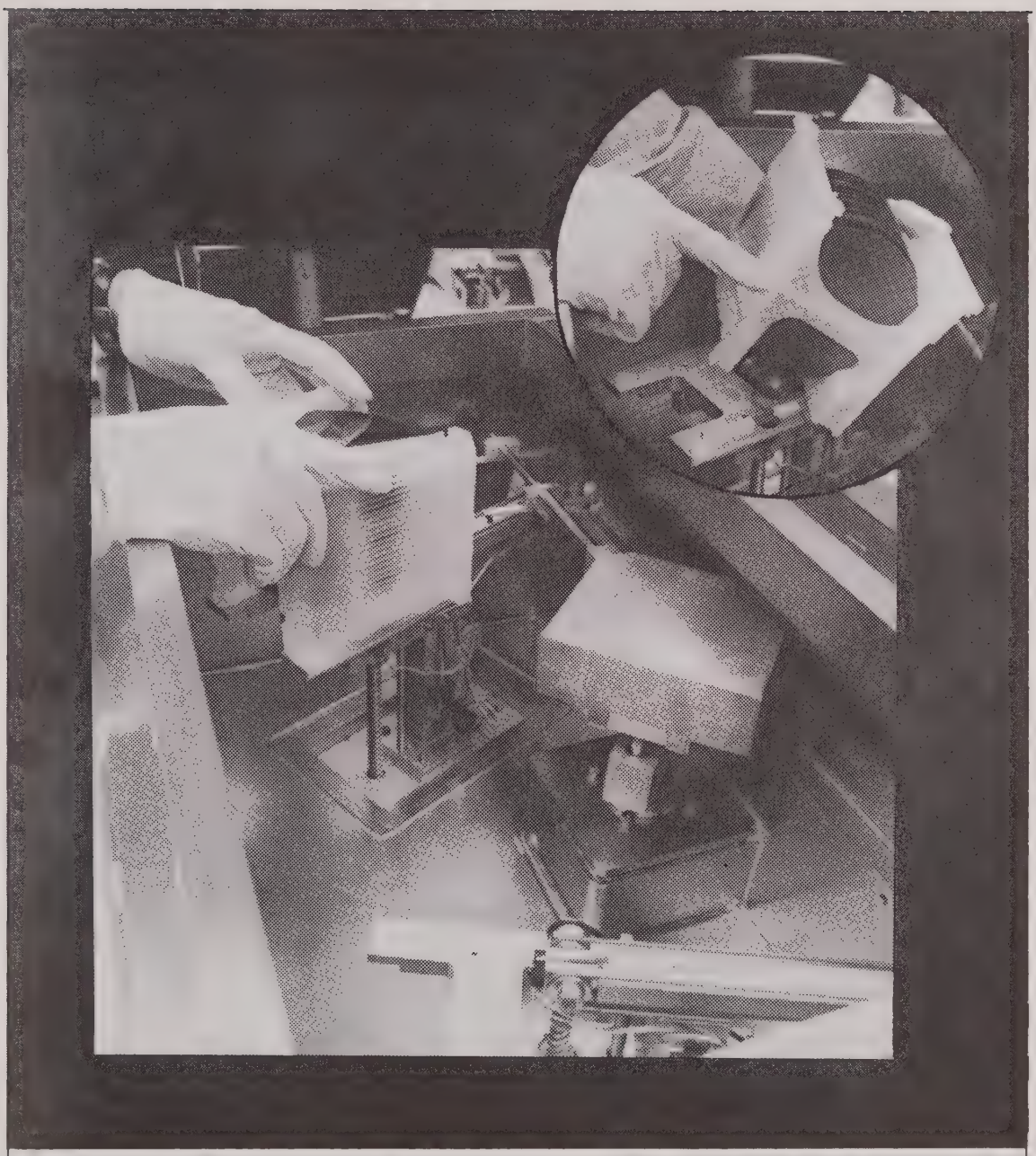


FIGURE 4-2

"PICK-AND-PLACE" CHAMBER, SHOWING WAFER CASSETTE

4.2 Model 4480 System Layout

Figure 4-1 shows a front view of the Perkin-Elmer Model 4480 Production Sputtering System. Each numbered item corresponds to a description, below.

Chapters 5, 6 and 7 contain detailed descriptions (and operating information where applicable) for all 4400-Series subsystems and controls.

4.2.1 Automatic Wafer Handling [ITEM No. 1]

Controlled by its own microprocessor, the automatic wafer handling module (in the AUTO mode) picks wafers to be processed from operator-loaded cassettes, places the wafers on the substrate pallet, removes processed wafers from the substrate pallet, and places processed wafers in cassettes which are removed from the system by the operator.

The operator may opt to use the sputtering system with the wafer handling module in the MANUAL mode, loading wafers onto the substrate pallet manually (a useful feature if substrates of an odd size or shape are to be processed).

The automatic wafer handling system is discussed in detail in Chapter 7.

4.2.2 Cassette Chamber Lid Activator [ITEM No. 5]

The Cassette Chamber Lid Activator is controlled by two UP/DOWN rocker switches located on the front surface of the cassette chamber lid activator panel. The operator must simultaneously select the same function on each switch in order to move the cassette chamber lid.

4.2.3 Pick-and-Place Computer [ITEM No. 6]

The Pick-and-Place computer controls all automatic wafer handling functions and, in the Model 4480, the motion of the load lock elevator and load lock pallet rotation motor. In addition, the Pick-and-Place computer drives the PE-6100 Data Terminal, interfacing with the MSC to display gas flow and error information. The Pick-and-Place computer is described more fully in Chapter 7 of this manual, and in Chapter 1 of the 4400-Series Service Manual.

4.2.4 Load Lock Lid Activator [ITEM No. 9]

The Load Lock Lid Activator is controlled by two UP/DOWN rocker switches located on the front surface of the load lock. The operator must simultaneously select the same function on each switch in order to move the load lock lid. The load lock lid is interlocked to the MSC, making it impossible to start a process sequence, pump the load lock or open the isolation valve (in the automatic mode only) without first closing the load lock lid.

4.2.5 Target Elapsed Time Indicator [ITEM No. 11]

OPTION

The target timer is an optional device used to record the number of sputtering-hours (measured to the nearest 1/10 hour) accumulated on each target.

4.2.6 Precision Table Rotation Speed Control [ITEM No. 12]

The precision table rotation speed controller allows the operator to select a table rotation in the range 0 - 10 rpm. Adjustments are made via switches and potentiometers on the front panel of the table drive unit.

The precision table drive also allows the operator to index the pallet within the process chamber (at speeds up to 5 rpm), and to pre-set a desired number of table rotations (at rotation speeds up to 10 rpm).

4.2.7 DGC-III Ion Gauge Controller [ITEM No. 13]

The Perkin-Elmer DGC-III controller monitors base pressure in both the process chamber and the load lock. Pressure set point values are programmed into the DGC-III front panel by the operator.

4.2.8 Ionization Switch Panel [ITEM No. 14]

The ionization gauge switch panel turns ON and OFF the Bayerd Alpert ion gauge tubes automatically. If the system is NOT equipped with a load lock Hi-Vac pump, there are only two (2) ion gauge tubes, either of which may be selected from the DGC-III controller (see Chapter 5).

Systems equipped with a load lock Hi-Vac pump are also equipped with three (3) ion gauge tubes. The DGC-III only allows the operator to choose between two (2) tubes. A rocker switch mounted on the front panel of the ion gauge controller is used to overcome this limitation:

"1" OR "2" SELECTED FROM DGC-III	ROCKER SWITCH POSITION	ION GAUGE TUBE SELECTED
1	N/A	LOAD LOCK
2	RIGHT SIDE IN	PROCESS CHAMBER
2	LEFT SIDE IN	PROCESS CHAMBER CRYO PUMP STACK

NOTE: THE DGC-III I/T BUTTON IS USED TO TOGGLE BETWEEN ION GAUGES AND THERMISTORS. THE SETTINGS DESCRIBED ABOVE APPLY ONLY WHEN ION GAUGES ARE SELECTED.

4.2.9 Load Lock Heater Power Supply [ITEM No. 15]

The load lock heater elements are powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON VIA MANUAL CONTROL (OVERRIDES MSC).

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 5 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 200 degrees Centigrade is acheived after five (5) minutes.

4.2.10 Process Pressure Regulator [ITEM No. 18]

OPTION

Included as part of the automatic gas option (with the Brooks controller[s]), the process pressure regulator is used a) to servo-control the throttle valve automatically in order to maintain a pre-set pressure level (at a selected gas flow rate) in the process chamber, or b) (in the MANUAL mode) to switch-select one of two throttle valve positions: 100% open or closed to a position which maintains chamber pressure at 10 milliTorr with a 40sccm gas flow.

4.2.11 Load Lock Turbo Pump Frequency Controller [ITEM No. 19]

Turbomolecular pump(s) reach operating speeds of about 35,000 rpm and must be slowly ramped up to speed. The turbo pump frequency controller automatically performs this function by multiplying the line frequency at a controlled rate to acheive the desired RPM. A meter on the front panel of this controller

indicates the range of turbo speed.

A switch point at 80% of full speed is used to interlock the high vacuum valve.

4.2.12 Water Flow Switches [ITEM No. 20]

Water flow switches are placed in series with the cooling system water lines, and maintain an OPEN switch position as long as water continues to flow through the switch. Interruption of water flow or switch failure causes the switch to CLOSE, which is interpretted by the MSC as a hard error (i.e., an error which aborts the process). Each flow switch is factory pre-set for the specific minimum flow rate recommended for the device being cooled (see service manual for further details).

4.2.13 DC Magnetron Control [ITEM No. 25]

OPTION

Regulates the output power of the 5 or 10 kW DC power supply to a constant volt-amp (VA) product.

4.2.14 RF Power/Voltage Stabilizer [ITEM No. 26]

OPTION

Maintains constant power or voltage for RF sputtering despite considerable variations in AC line voltage, gas pressure, work characteristics, and temperature. Selecting POWER maintains pre-set power while varying the voltage. Selecting VOLTAGE maintains pre-set voltage while varying the power.

4.2.15 Servo Match™ Panel [ITEM No. 27]

OPTION

Automatically servos the RF tuning and load circuits located in the sputter head assembly, adjusting the circuits for minimum reflected power and the load circuit to compensate for the impedence of a target, or selection of a different gas or power level.

4.2.16 Process Chamber Turbo Pump Frequency Controller [ITEM No. 28]

OPTION

Same as Load Lock Turbo Frequency Controller (ITEM No. 19, above).

4.2.17 In-Process Heater Power Supply [ITEM No. 29]

OPTION

The in-process heater element is powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON.

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 8 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 350 degrees Centigrade is acheived after five (5) minutes.

4.2.18 Brooks Automatic Gas Controllers [ITEM No. 30]

OPTION

Independent flow levels of one to three gases are controlled by optional Brooks gas flow controllers. Both process gas pressure and individual gas flow levels are independently programmed via the MSC. Gas flow levels are conveniently displayed on the PE-6100 Data Terminal in sccm (Standard Cubic Centimeters per Minute).

Chapter 5

SYSTEM CONTROLS

Most subsystems and controls are common to all 4400-Series systems, while some are available only on specific models. Each component discussed below may be assumed to be common to ALL systems unless otherwise noted.

The following subsystems are described in this chapter:

5.1 Load Lock

5.2 Process Chamber

5.3 8" Round Sputter Head Assembly (Model 4400)

5.4 Delta™ Sputter Head Assembly (Models 4450/4480)

5.5 Power Supplies

5.6 DGC-III Ion Gauge Controller

5.7 The PE-6100 Data Terminal

5.8 Safety Features

The most important element of the control system, the Main System Controller (MSC), is sufficiently complex to warrant a separate chapter. It is described in Chapter 6.

The Automatic Wafer Handling System (an advanced feature of the Model 4480 Production Sputtering System) is described in Chapter 7.

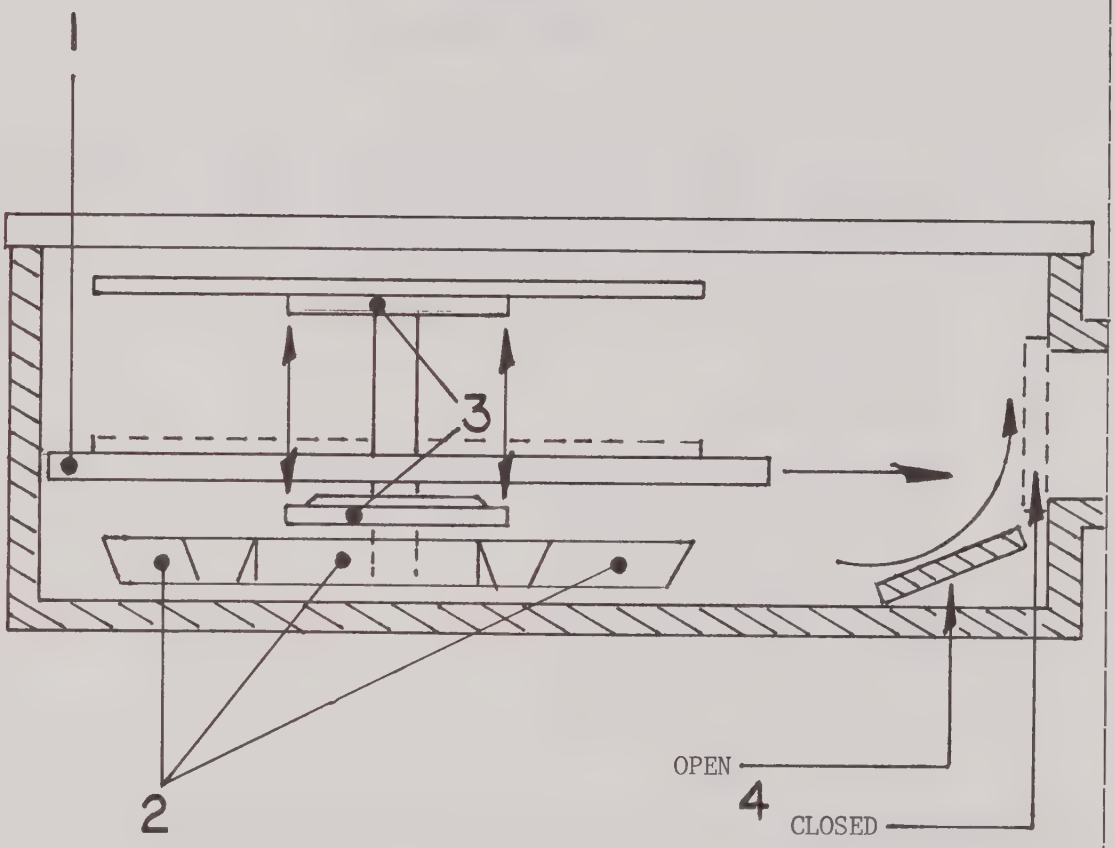


FIGURE 5-1

LOAD LOCK (INTERIOR)

1. SUBSTRATE PALLET CARRIAGE
2. LOAD LOCK RADIANT HEATERS (STANDARD ON MODEL 4480 ONLY)
3. LOAD LOCK ELEVATOR
4. LOAD LOCK ISOLATION VALVE (SHOWING OPEN AND CLOSED POSITIONS)

5.1 System Load Lock

The load lock assembly shown in Figure 5-1 is mounted at the left end of the sputtering system and rests on top of the system main frame, on which the process chamber is also mounted. (On the Model 4480, the load lock is located immediatedly to the right of the automatic wafer handling module cassette chamber.)

The 4400-Series load lock permits the loading, pre-heat processing (optional on Models 4400 and 4450, standard on Model 4480), and unloading of substrates while the process chamber is completely isolated from atmosphere. It is designed specifically for rapid transfer of substrates from atmosphere to high vacuum (5×10^{-7} Torr in less than 3.5 minutes). It also functions to keep the targets and process chamber at high vacuum, thus reducing the possibility of oxidation, condensation, and atmospheric contamination. The load lock helps assure repeatability and makes it unnecessary to perform a target pre-cleaning operation before processing each new batch of substrates for most common sputtered materials.

The load lock chamber is typically rough pumped to 150 milliTorr by the mechanical pump (which is shared with the process chamber vacuum system) and brought to high vacuum by the load lock turbo pump (optional on Models 4400/4450, standard on Model 4480)\ before the load lock isolation valve is opened to allow transfer of the substrate pallet between load lock and process chamber. Operation of the pumps is regulated by the MSC.

5.1.1 Load Lock Heater

The load lock heater consists of quarts lamps, reflectors, and a time-proportional temperature controller. Switching logic is provided by the MSC. Its purpose is to aid in the removal of water vapor from the substrates before they are introduced into the process chamber.

The load lock heater applies heat (up to 200 degrees Centigrade) to a pallet loaded with substrates before transferring the pallet into the process chamber. The ENABLE/CYCLE START command from the MSC turns the heater on automatically while the load lock is brought to high vacuum by its turbomolecular pump (load lock turbo pump optional on Models 4400/4450). When a pre-set time value is met, the heater power supply is turned off and the load lock isolation valve (i.e., door) is opened, allowing the substrate pallet to be transferred into the process chamber.

The load lock heater power supply is mounted on the sputtering system front panel.

5.1.2 Load Lock High Vacuum Pump

The 170 liter-per-second turbomolecular pump is used to remove water vapor and other contaminants from the load lock chamber, producing a higher vacuum in the load lock that allows the process chamber to a) remain cleaner, and b)

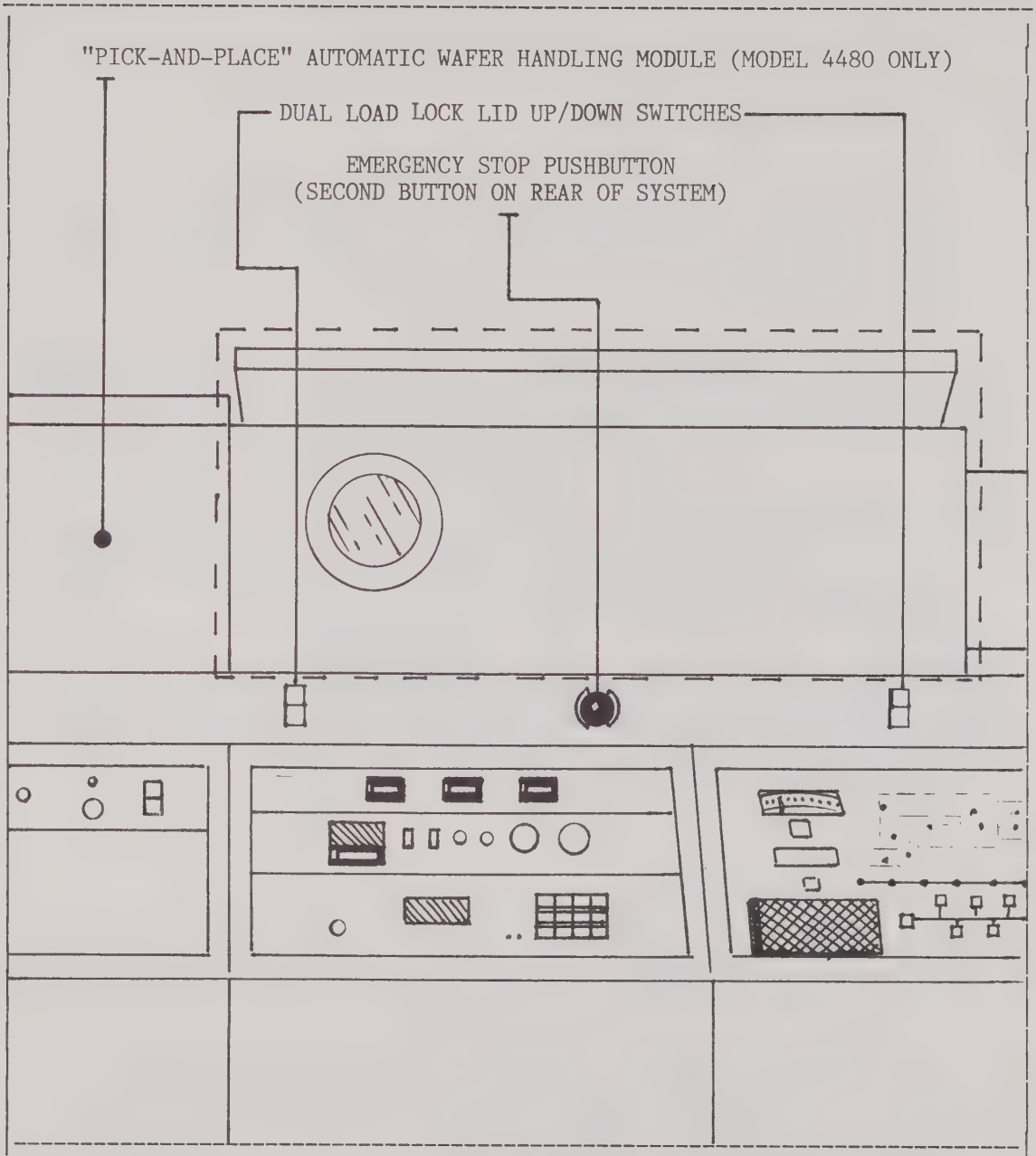
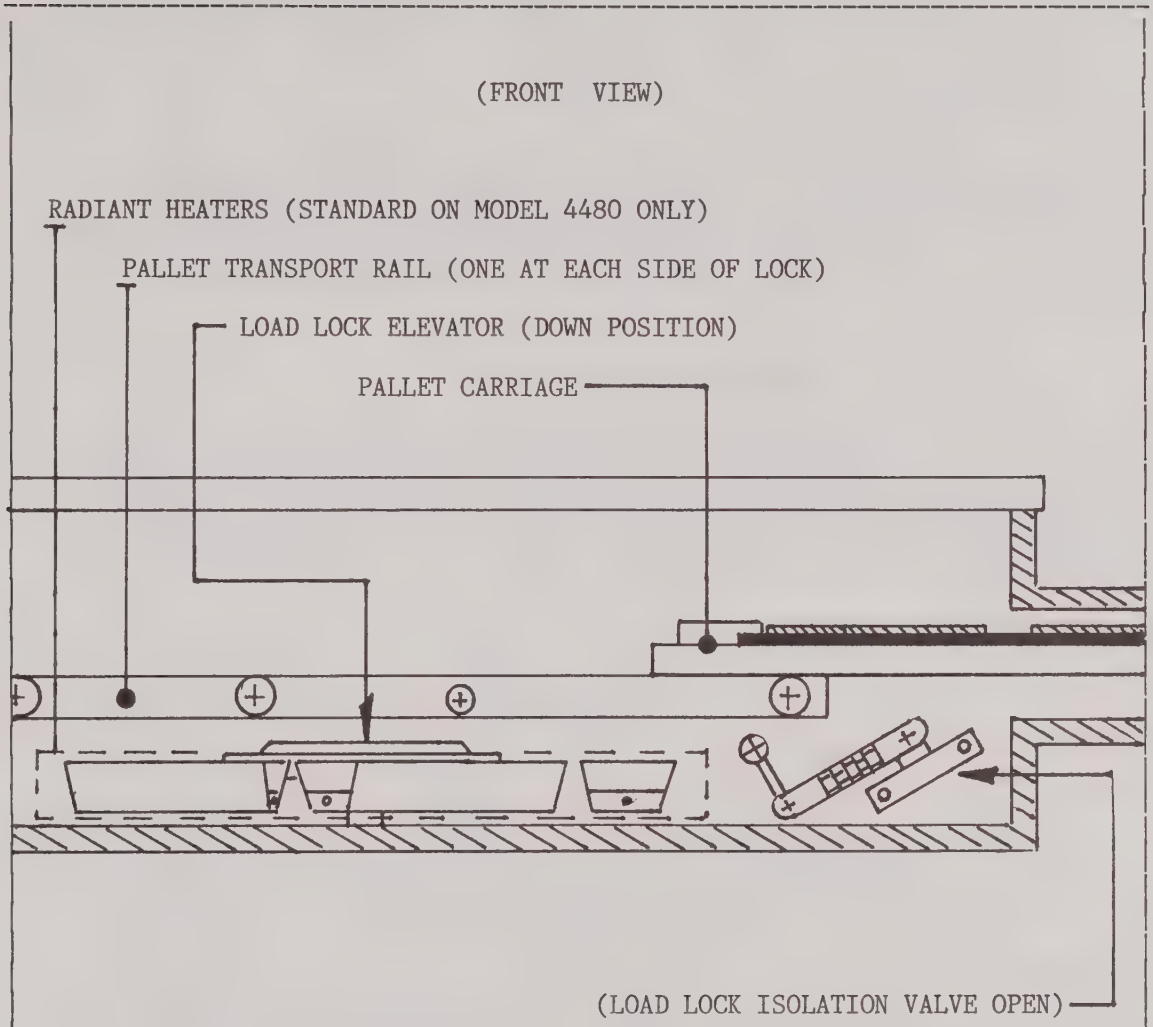

"PICK-AND-PLACE" AUTOMATIC WAFER HANDLING MODULE (MODEL 4480 ONLY)
DUAL LOAD LOCK LID UP/DOWN SWITCHES
EMERGENCY STOP PUSHBUTTON
(SECOND BUTTON ON REAR OF SYSTEM)

FIGURE 5-2

LOAD LOCK (FRONT VIEW)


(FRONT VIEW)
RADIANT HEATERS (STANDARD ON MODEL 4480 ONLY)
PALLET TRANSPORT RAIL (ONE AT EACH SIDE OF LOCK)
LOAD LOCK ELEVATOR (DOWN POSITION)
PALLET CARRIAGE
(LOAD LOCK ISOLATION VALVE OPEN)
(TO PROCESS CHAMBER) ---------->
FIGURE 5-3
SUBSTRATE PALLET BEING TRANSFERRED INTO OR OUT OF
THE PROCESS CHAMBER

recover to high vacuum more quickly. In most sputtering processes this can result in a superior, more repeatable product.

5.1.3 Load Lock Lid

Pallets are installed and removed through the load lock lid, which forms the top surface of the load lock assembly. On systems NOT equipped with automatic wafer handling (i.e., Models 4400 and 4450), the load lock lid must be opened each cycle to remove processed wafers and load wafers to be processed.

5.1.3.1 Load Lock Lid UP/DOWN Control Panel

The load lock lid is raised via the LOAD LOCK LID UP/DOWN control, located on the front panel of the load lock assembly (see Figure 5-2). The load lock lid UP/DOWN control is equipped with two identical UP/DOWN rocker switches, mounted at opposite ends of the UP/DOWN control panel. Both switches must be moved to the same position at the same time in order to activate the load lock lid hoist.

5.1.4 Rotating Table Elevator

(See Figure 5-3)

MODELS 4400/4450

A pneumatic elevator automatically raises the pallet to the top of the load lock chamber each time the load lock lid is opened and lowers it each time the operator initiates the load sequence by closing the load lock lid.

MODEL 4480

A stepper motor automatically raises the pallet to the correct position for automatic wafer loading/ unloading ONLY WHEN THE AUTOMATIC WAFER HANDLING SYSTEM IS IN THE 'AUTO' MODE. The elevator may be raised to this same position manually using the manual elevator UP/DOWN toggle switch located on the MSC (MSC must be in the MANUAL key switch position).

During the load operation, the elevator places a loaded pallet on the U-shaped carriage mechanism in the load lock chamber. The carriage transports the pallet through the load lock isolation valve into the process chamber by means of chain drive wheels, and places it on the anode/substrate table. Inside the process chamber, the pallet is lifted off the carriage by the anode/substrate table (when the table moves to its UP position). The carriage then returns to the load lock chamber, and the load lock isolation valve closes. The transport sequence is reversed during the unload operation.

5.1.5 Load Lock Isolation Valve

The load lock isolation valve (also known as the lock isolation valve, or the load lock inner door) consists of an O-ring-sealed door, and is NOT to be confused with the load lock lid. The lock isolation valve separates the load

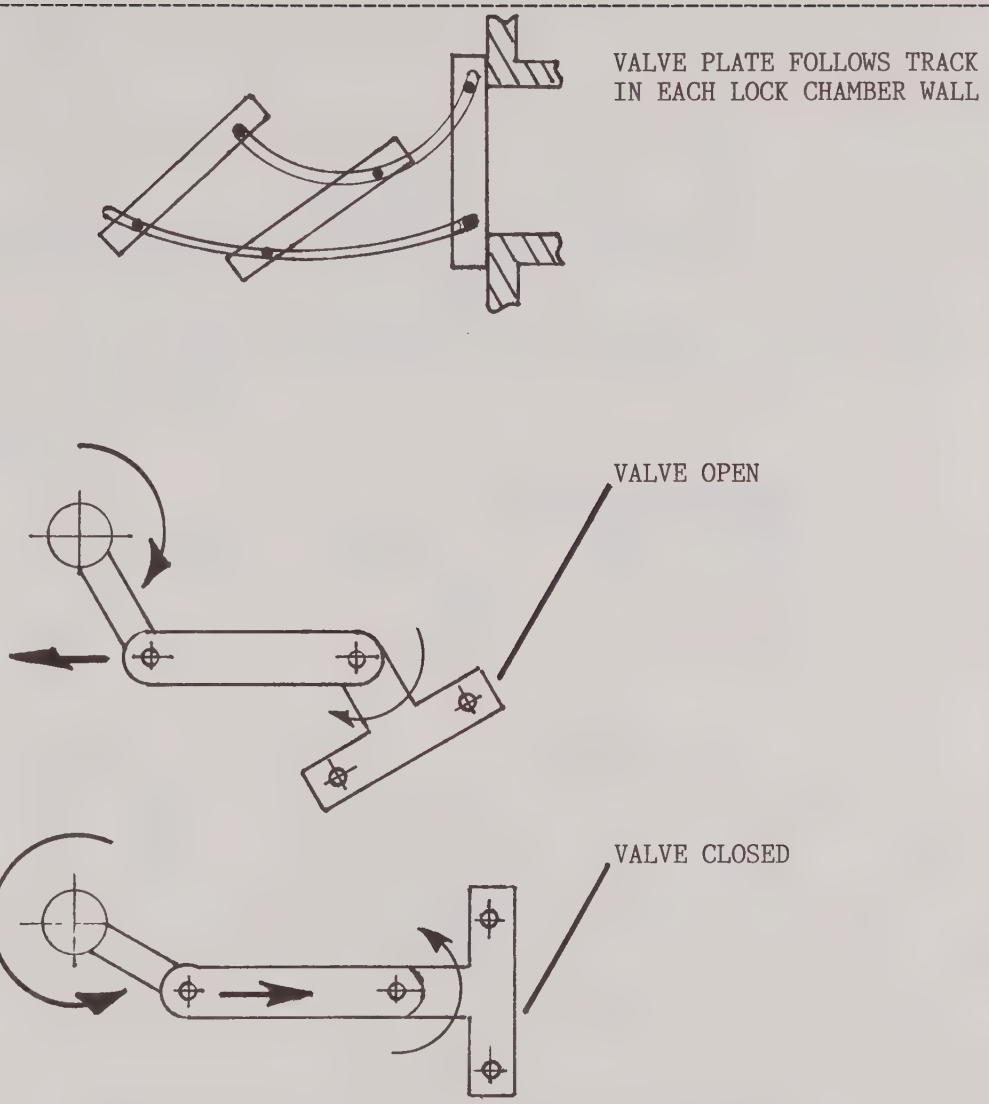
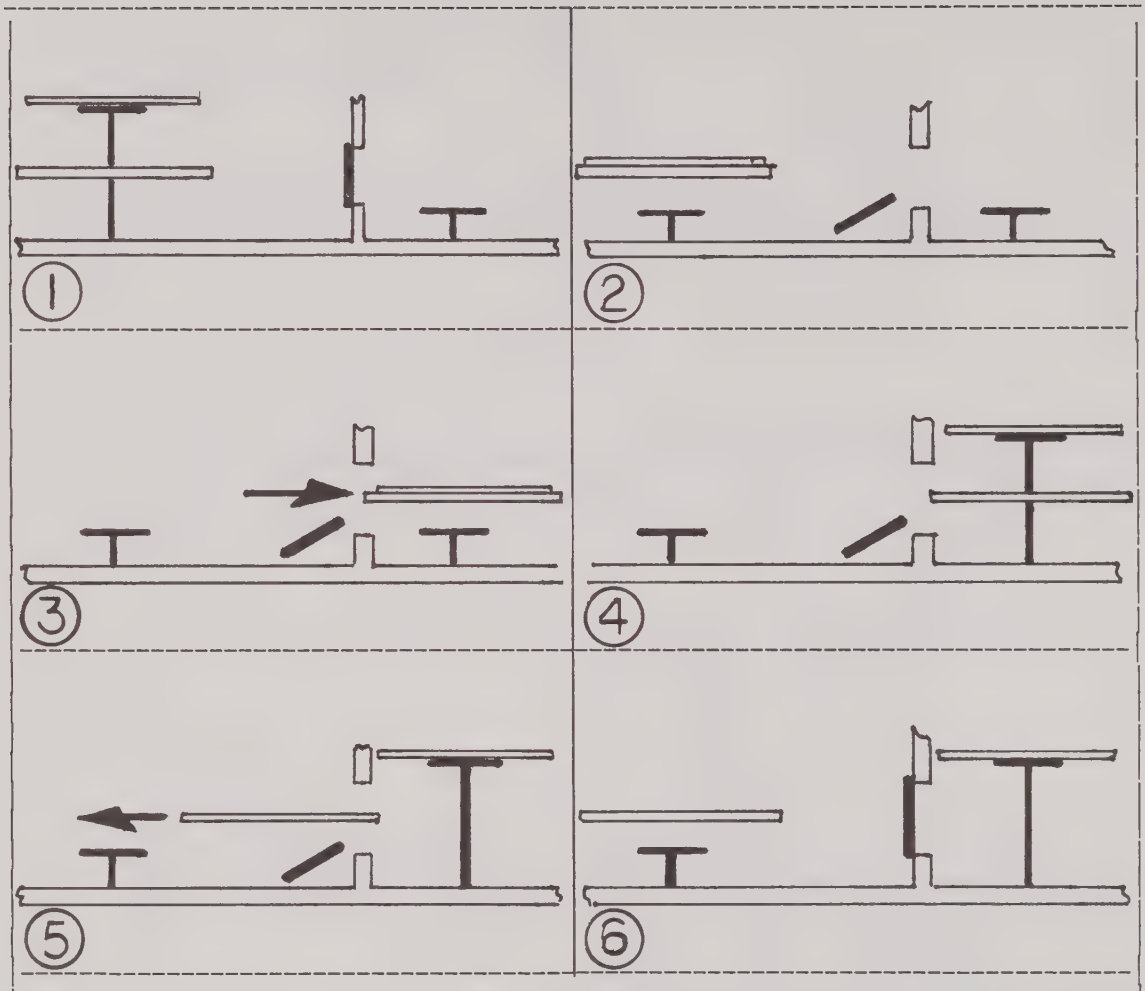


FIGURE 5-4

LOAD LOCK ISOLATION VALVE OPERATION, VIEWED FROM FRONT OF SYSTEM



NOTE

THE LOCK ISOLATION DOOR REMAINS OPEN WHILE THE PALLET CARRIAGE MECHANISM MOVES IN AND OUT OF THE PROCESS CHAMBER.]

FIGURE 5-5

THE PALLET TRANSFER SEQUENCE

lock from the process chamber. The load lock lid is the top surface of the load lock and opens to provide operator access to the interior of the load lock.

When the load lock isolation valve is closed, the load lock may be vented to atmosphere without disturbing the vacuum level of the process chamber. When the load lock is pumped to vacuum, the lock isolation valve remains closed until the vacuum set point is reached, at which time it opens to permit substrate pallet transport. (See Figures 5-4 and 5-5.)

The lock isolation valve is controlled automatically when the Main System Controller (MSC) is in the AUTOMATIC mode. It may be opened and closed under direct operator control when the MSC is in the MANUAL mode, via a toggle switch located on the front panel of the MSC. (Operating Instructions for the MSC are given in Chapter 6.)

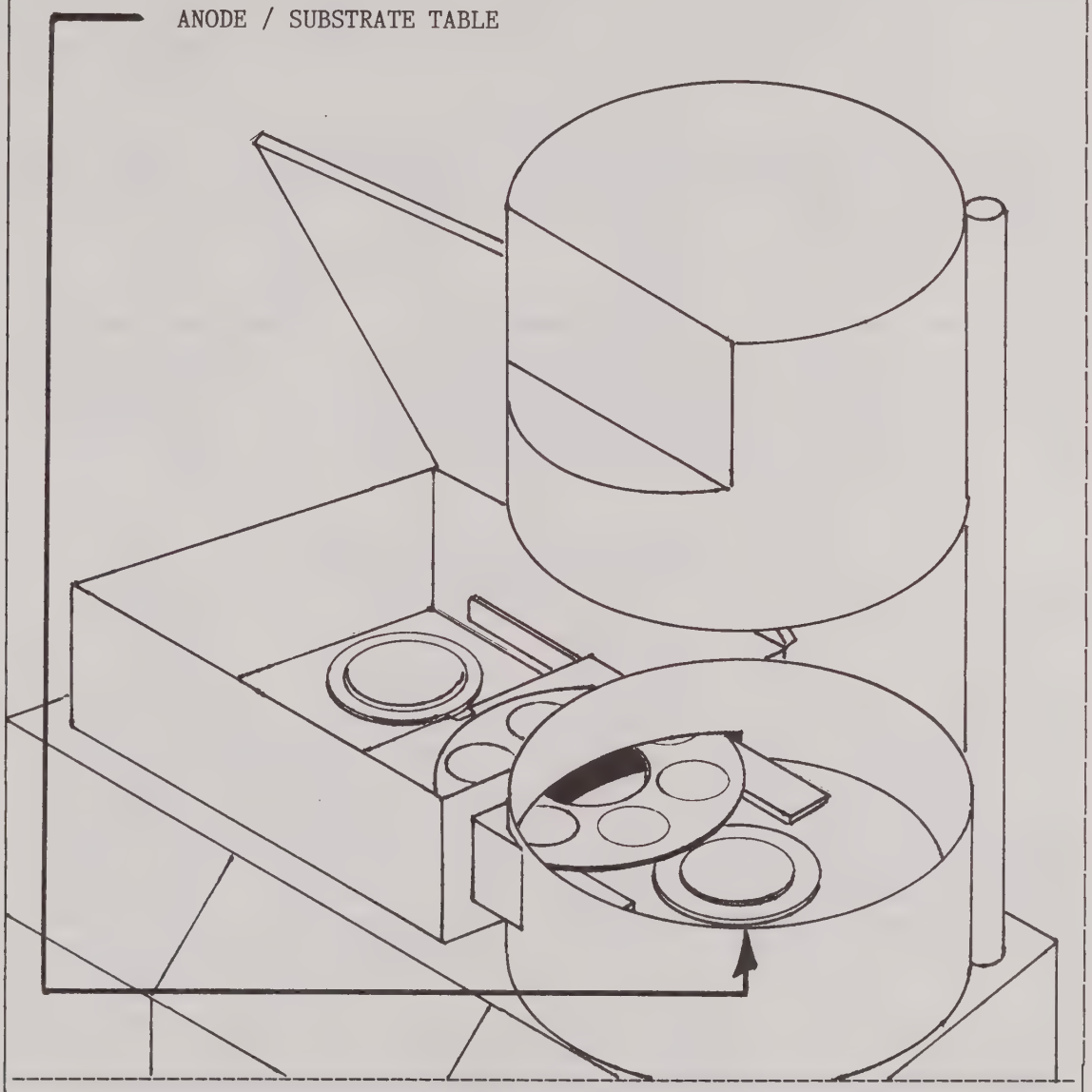
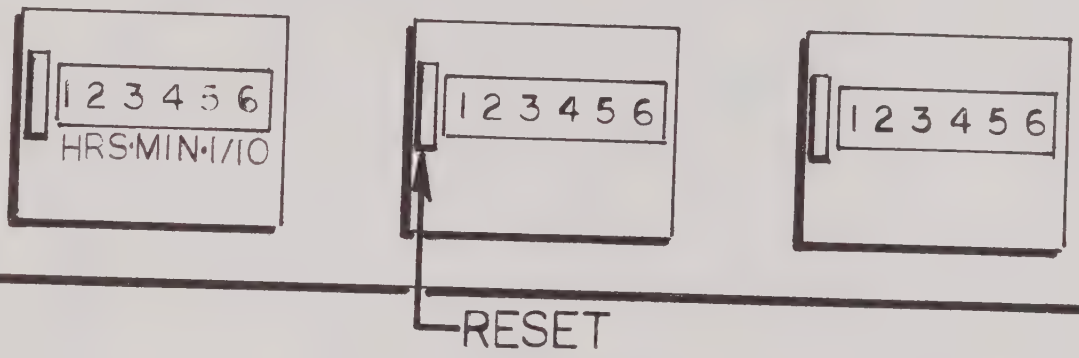


FIGURE 5-6

3/4 VIEW OF 4400-SERIES SPUTTERING SYSTEM (SPUTTER HEAD RAISED)

SHOWING PALLET PASSING THROUGH LOAD LOCK ISOLATION VALVE

TARGET ELAPSED TIME INDICATOR (FOR THREE [3] TARGETS)



PRECISION TABLE ROTATION CONTROL

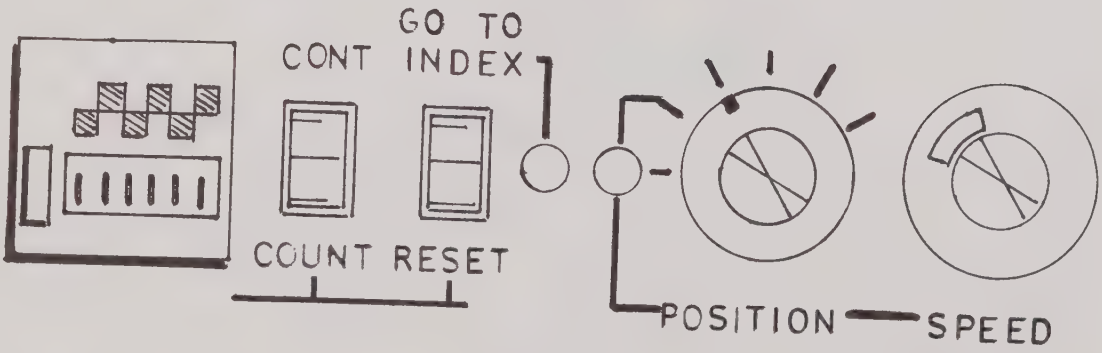


FIGURE 5-7

SYSTEM CONTROLS

5.2 Process Chamber

The process chamber for the 4400-Series systems, shown in Figure 5-6, is a 28" diameter, stainless steel, water-cooled cylinder within which the sputtering and etching operations take place.

5.2.1 Anode/Substrate Table

(See Figure 5-6)

The anode/substrate table consists of an aluminum annular table with a silver-plated, stainless steel ground shield. Normally, the substrate table is continuously rotated during processing by a precision rotation speed control, to provide even wafer-to-wafer coating uniformity. An indexing feature and rotation counter are standard.

5.2.1.1 Precision Table Rotation Speed Control

The precision table drive is mounted on the front panel of the sputtering system (see Figure 5-7). It utilizes a DC motor and a feedback loop to maintain precisely the selected speed. The range for this drive assembly is 3 rph to 10 rpm, and it is suitable for either single- or multi-pass deposition. The precision drive is constant and repeatable from run to run.

Before loading a pallet into the load lock (MANUAL wafer handling) the substrate table must be set at INDEX by placing the table drive controller rocker switch in the GO TO INDEX position. (In the AUTOMATIC wafer handling mode, Indexing is accomplished automatically.) After the pallet is transferred into the process chamber, the table will rise to either the etch or sputter position, and rotation will commence as soon as a process is selected and gas turned on.

When the table drive rocker switch is in the CONTINUOUS position, rotation will continue as long as the ROTATE/STOP rocker switch is in the ROTATE position. When the table drive rocker switch is in the COUNT position and the ROTATE/STOP rocker switch is in the ROTATE position, the table will complete a pre-set number of rotations. After each rotation, the AT INDEX light will momentarily light, and the REV. COUNTER will decrement one digit. Rotation continues until the counter reaches zero. (THE AUTOMATIC INDEXING FUNCTION IS PRECISE ONLY UP TO A ROTATION SPEED OF 5 RPM.)

5.2.2 Meissner Trap Assembly

The Meissner trap is located inside the process chamber, below the annular table. It offers maximum water vapor pumping capability (up to 30,000 liters per second) when liquid nitrogen is circulated through the assembly. This "auxiliary cryo pump" continues to pump even when the main cryo pump (if system is so equipped) is throttled during the sputtering process.

SERVO-MATCH CONTROLLER

IN-PROCESS HEATER POWER SUPPLY

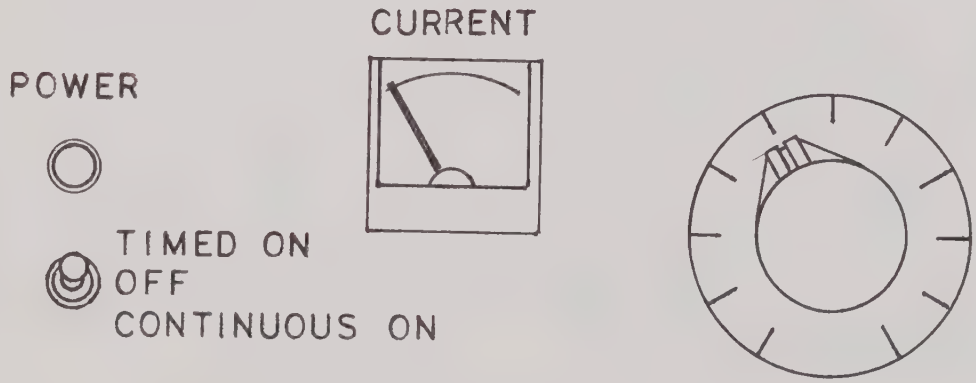


FIGURE 5-8

SYSTEM CONTROLS

LN_2 should not be introduced into the Meissner trap until process chamber pressure falls below 5×10^{-7}. A three position LN_2 switch (OFF, LN_2 CONT[inuous], LN_2 Timed) on the MSC regulates the flow. (In the TIMED mode, LN_2 is filled until a sensor determines that the trap is full. Once a FULL signal is received by the MSC, three (3) minutes elapse before the sensor is polled again. Each time LN_2 is added to trip the sensor, a new three (3) minute cycle is initiated.)

The Meissner trap assembly has over 160 square inches of surface area. Its pumping speed of more than 30,000 liters-per-second (with LN_2) for water vapor is computed with a conservative sticking coefficient of 75%. The LN_2 Meissner trap is standard equipment on all 4400-Series Production Sputtering Systems. A special coil for Freon™ "Polycold" is available as an option.

Removing water vapor allows the system to deposit low resistivity, highly specular aluminum alloy films such as aluminum-silicon or aluminum-silicon-copper.

A Meissner Hot Purge system minimizes chamber venting cycle time by accelerating the warming of the trap to prevent moisture condensation on the cold trap when it is exposed to atmosphere. Purging is accomplished using heated dry nitrogen.

5.2.3 In-Process Substrate Heater

A process chamber heater is available to provide substrate heating immediately before, during, or after deposition. In some cases, this can enhance film adhesion and provide control of grain size and stoichiometry.

HEATER FOR MODEL 4400

Optionally installed in target position No. 4, the radiant heater produces a process chamber temperature of 350 degrees Centigrade.

HEATER FOR MODELS 4450/4480

Optionally installed in any target position (but usually in Position 3), the radiant quartz heater REPLACES a cathode assembly. The heater produces process chamber temperatures of 350 degrees Centigrade.

The in-process heater power supply is mounted on the sputtering system front panel (see Figure 5-8).

5.2.4 Shutters and Deposition Shields

(See Figure 5-9)

Shutters are metal plates that are moved as necessary to separate the anode/substrate table from any or all of the cathodes. The shutters are closed during target pre-cleaning to protect the anode/substrate table, and during sputter-etching to protect the cathodes.

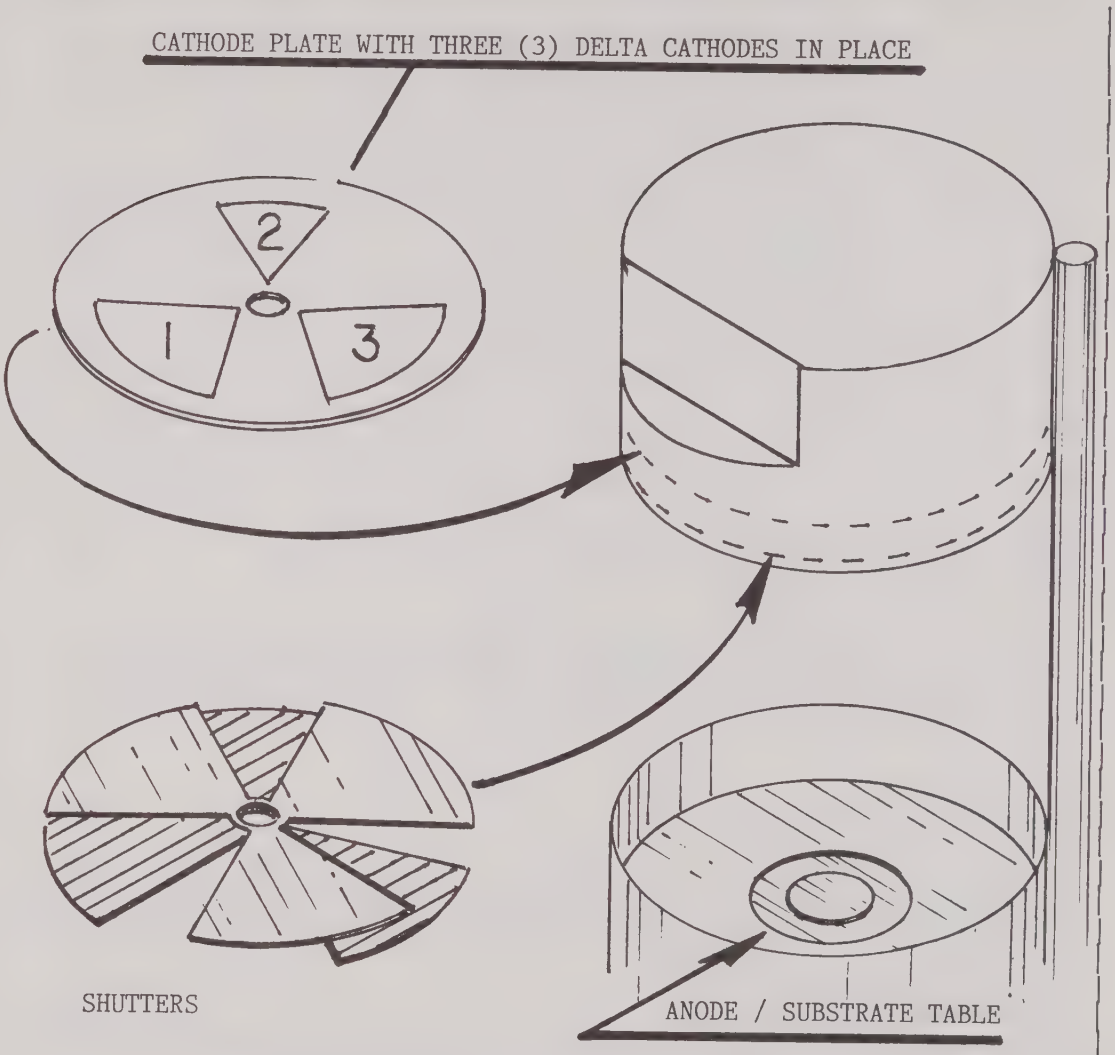


FIGURE 5-9

SPUTTER HEAD FROM MODEL 4450 OR 4480 (DELTA CATHODE TYPE), SHOWING VERTICAL ARRANGEMENT OF CATHODES AND SHUTTERS ABOVE THE ANODE / SUBSTRATE TABLE.

Deposition shields prevent sputter deposition in areas where deposits could adversely affect system operation (see Item 2, Figure 5-9). They also improve process uniformity in 4450 and 4480 systems, since shapers are mounted directly to each shutter opening. As the shields become coated with sputtered material, they can easily be removed and exchanged for clean shields, with a minimum of down time (see Appendix A, "Periodic Maintenance").

5.2.5 View Ports

(See Figures 5-9 and 5-10)

The view port, a 6" O.D. flange with a 3-1/2" clear view into the process chamber, permits the operator to monitor the process chamber and to take immediate action should any problem arise. Sputtered material is deposited on an internal Pyrex™ glass which may be replaced, as required, when deposition shields are exchanged. (Pyrex™ is used in order to protect the viewer's eyes from potentially dangerous ultraviolet radiation.) The load lock is also equipped with a view port.

5.2.6 Hoist Mechanism

(See Figure 5-9)

The 4400-Series systems are equipped with a heavy-duty, self-locking, electro-mechanical hoist to permit the processing chamber to be opened easily. A hoist interlock safety switch prevents the hoist from being activated when the process chamber is under vacuum (the hoist can ONLY be activated once the chamber is vented to atmosphere).

The hoist is actuated via an UP/DOWN toggle switch located on the front panel of the MSC.

5.2.7 Emergency Stop Pushbutton

(See Figure 5-10)

Depressing an Emergency Stop pushbutton , located on the front and rear of the sputtering system, on the RF generator (if any), and 10kW DC power supply (if any), immediately closes all gate valves and turns the main system circuit breaker OFF. Every component in the system is turned OFF, including the RF generator(s), DC power supply(ies), and all pumps.

RESET the system following an Emergency Stop from the wall-mounted main utility box.

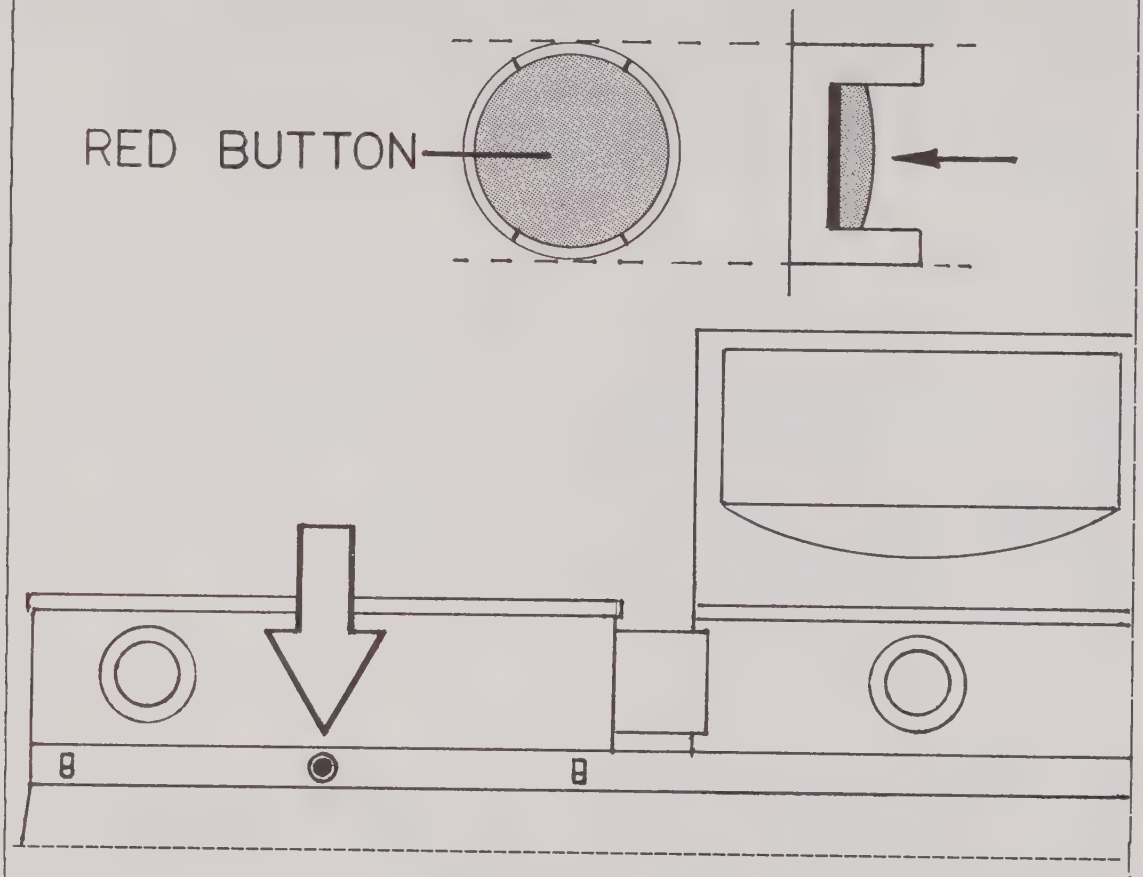


FIGURE 5-10

EMERGENCY STOP PUSHBUTTONS

LOCATED ON THE FRONT AND REAR OF THE SYSTEM, ON THE RF GENERATOR (IF SYSTEM SO-EQUIPPED), AND ON THE 10KW DC POWER SUPPLY (IF SYSTEM SO-EQUIPPED), THESE BUTTONS ARE TO BE DEPRESSED MANUALLY BY THE SYSTEM OPERATOR IN THE EVENT OF FIRE, FLOODING, OR DANGER OF ELECTROCUTION. (OPENS WALL-MOUNTED MAIN CIRCUIT BREAKER.)

CAUTION

IF THE SYSTEM IS LEFT IN THE POWER-DOWN MODE FOR LONGER THAN FIVE(5) MINUTES, THE PROCESS CHAMBER CRYO PUMP (IF THE SYSTEM IS SO EQUIPPED) WILL HAVE TO BE REGENERATED. CRYO PUMP REGENERATION TAKES ABOUT FOUR (4) HOURS.

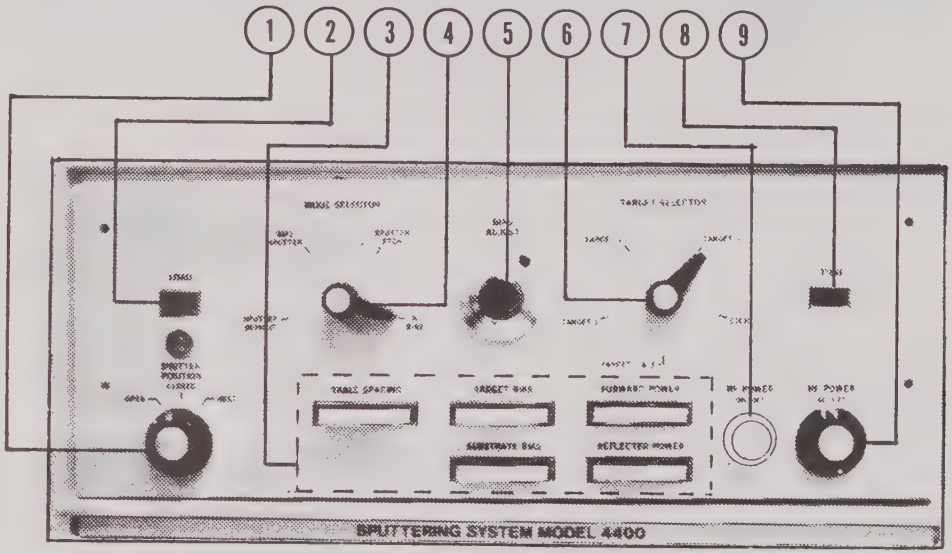


FIGURE 5-11

MODEL 4400 SPUTTER HEAD FRONT PANEL

1. SHUTTER POSITION SELECTOR
2. LOAD TUNE SWITCH
3. ANALOG METERS
4. MODE SELECTOR SWITCH
5. BIAS ADJUST CONTROL
6. TARGET SELECTOR SWITCH
7. RF POWER ON / OFF PUSHBUTTON
8. TUNE SWITCH
9. RF POWER ADJUST CONTROL

5.3 Sputtering Head Assembly - Model 4400

5.3.1 Control Panel

The Model 4400 system sputter head assembly includes a complete range of controls to regulate the system parameters affecting the sputtering and etching process. Adjusting the system to produce the desired result requires a certain amount of experimentation. Some experimentation with a specific machine at various settings (using sample or reject wafers) should suffice to determine the correct settings for any given process.

The following controls and indicators are located on the control panel of the sputter head assembly (see Figure 5-11).

5.3.1.1 Shutter Position Switch [ITEM No. 1]

Allows the shutter to be closed during the sputter etch mode, and open to the selected target or targets for sputter deposition.

5.3.1.2 Load Control Switch [ITEM No. 2]

The load control switch drives a motor which controls the setting for the RF load tuning coil. It is used in conjunction with the TUNE switch. Both switches, used together, match (manually) the RF power to the load. They are overridden by the Servo-Match™ controller when the system is operated in the automatic tune mode.

5.3.1.3 Table Spacing Meter[ITEM No. 3]

Measures the distance between the substrate table and the target surface on a scale from 0" - 5".

5.3.1.4 Target Bias Meter [ITEM No. 3]

Measures the voltage applied to the target.

5.3.1.5 Substrate Bias Meter [ITEM No. 3]

Measures the voltage applied to the substrate table.

5.3.1.6 Forward Power Meter [ITEM No. 3]

Measures the total power output of the RF generator. (A 2kW meter is installed if a 2kW power supply is to be used; 3kW for a 3kW power supply.)

5.3.1.7 Reflected Power Meter [ITEM No. 3]

Measures the amount of RF power reflected back from the sputter head assembly or substrate table to the RF generator, due to impedence mismatching between the power supply and load. For best results, reflected power should be no more than 25 watts at maximum load.

5.3.1.8 Mode Selector [ITEM No. 4]

Allows selection of the following operating modes:

Sputter Deposit	[RF OR DC] RF or DC power is applied to the selected target. The substrate table is grounded. The Target Bias meter displays RF or DC power applied to the target.
Bias Sputter	[RF ONLY] Most RF power is applied to the target, but a small amount of RF power (up to 10%) can be applied to the substrate table. Consequently, substrates also are bombarded by ions, but to a much lesser degree than is the target. In many cases this technique yields higher quality deposits and better step coverage than RF sputtering with grounded substrates. Bias is read on the RF BIAS meter.
Sputter Etch	[RF ONLY] RF power (1 kW maximum) is applied to the substrate table, and material is removed (etched away) from the substrate by ion bombardment. Self-bias is displayed on the TARGET BIAS meter.

5.3.1.9 BIAS ADJUST CONTROL [ITEM No. 5]

Active only in the BIAS SPUTTER operating mode. Adjusts percentage of RF power applied to the substrate table. Varying amount of power varies negative self-bias on the table. Bias is displayed on the SUBSTRATE BIAS meter (-500V full scale). Substrate bias is normally in the range 0 - 10% of target bias.

5.3.1.10 Target Selector Switch [ITEM No. 6]

Connects output of the matching circuit to any of the four (4) targets and/or the substrate table. The target selector switch has five positions. In the TARGET 1 position, RF power is applied to TARGET 1 (the target on the left as viewed from the front of the system). This switch allows power to be applied to any of the three targets separately (or using the power splitting option, to targets 1 and 3 simultaneously). TARGET 2 is the rear target. TARGET 3 is on the right. Target 4 is in front. In the ETCH position, RF power is applied to the substrate table.

5.3.1.11 RF Power Switch [ITEM No. 7]

Activates the RF power supply to couple the RF power to the sputtering head assembly (or substrate table). The generator is interlocked so that power cannot be applied while the chamber is at atmosphere.

5.3.1.12 Tune Control Switch [ITEM No. 8]

The tune control switch drives a motor which controls the setting for the RF tuning capacitor. It is used in conjunction with the LOAD switch. Both switches are used together to match the RF power to the load manually. They are overridden by the Servo-Match™ controller when it is operated in the automatic tune mode.

5.3.1.13 RF Power Adjust Control [ITEM No. 9]

Governs power output from the RF power generator.

5.3.2 Cathodes

The cathode is a negatively-charged electrode, the source of the material sputtered onto the substrates. The cathode assembly consists of the target itself, a backing plate, insulators, cooling tubes, and the necessary electrical connections. Target materials are attached to the target backing plates using a solder-bonding technique.

Models 4450/4480 are designed to use Delta™ cathodes. The Model 4400 uses 8" round RF or DC cathodes, which may also be adapted for use with the Models 4450/4480.

Target-changing, using either Delta™ or 8" round cathodes, is a simple procedure which may be performed by the operator in only a few minutes.

5.3.3 Shutters

Shutters are disks or plates (depending on target configuration) mounted on the sputter head assembly and actuated from the sputter head assembly control panel. They are used to separate the target(s) from the substrate pallet during sputter etching, to prevent material removed from the substrates from contaminating the target(s). They also are closed for target pre-cleaning (short duration ONLY) prior to sputter deposition.

Shutters are also used to open the desired target(s) selectively to the substrates for sputtering.

5.3.4 Dark Space Shields

The dark space shield surrounds the target assembly at a distance of 1/8" from the target to prevent plasma from being generated on the sides of the targets. It focuses the discharge and provides grounding surfaces for the discharge.

5.3.5 Cross-Contamination Shields - Models 4450/4480

Standard on all 4400-Series systems, these prevent material sputtered from one target from contaminating other targets.

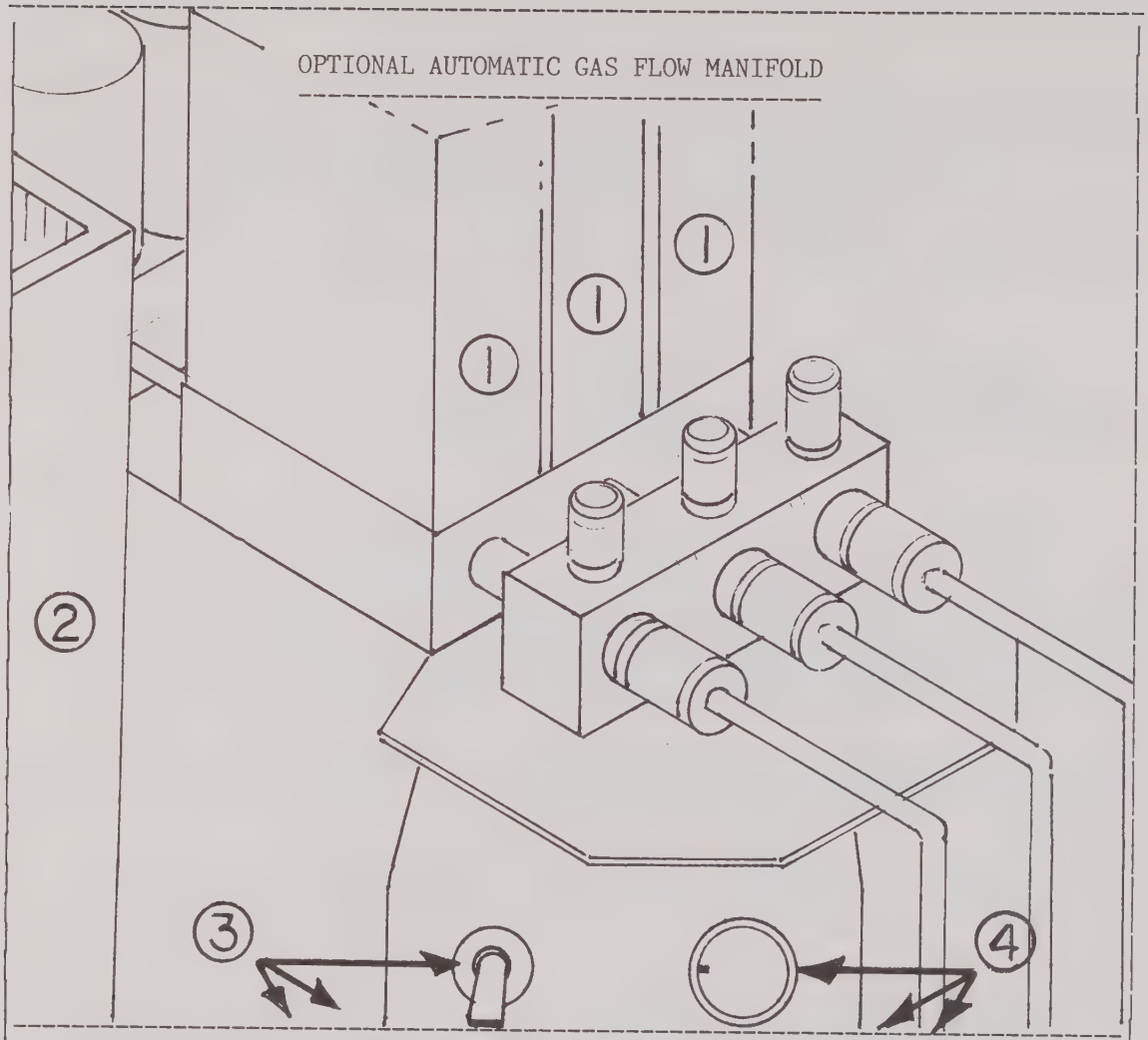


FIGURE 5-12

OPTIONAL BROOKS AUTOMATIC GAS FLOW SYSTEM

1. BROOKS GAS FLOW CONTROLLERS (3)
2. SPUTTERING HEAD HOIST
3. MANUAL GAS ON / OFF VALVES (3)
4. MANUAL MICROMETER VALVES (3)

5.3.6 Shapers

In the 4400-Series systems, using 8" round DC or RF magnetron targets creates a circular, symmetrical deposition pattern. Substrates are typically placed on the annular substrate table and rotated continuously beneath the target during deposition. Uniformity is achieved by "shaping" the vapor flux with shields (shapers) through which have been cut specially designed apertures. Shapers are always used when sputtering from 8" round targets.

Shapers are available as an option for the Model 4400.

Shapers are designed to be quickly and easily removed for replacement or cleaning whenever the process chamber is vented.

5.3.7 Brooks 1, 2, or 3 Automatic Gas Flow Controllers

(See Figure 5-12.)

Brooks automatic gas controllers are available as options for all 4400-Series systems. This option allows the operator to program desired flow levels of one or more gases into the process chamber via the MSC, as part of an automatic sequence. Brooks controllers are mounted to the right rear of the sputter head assembly, behind the manual gas flow valves.

Included as part of the Automatic gas control option is an automatic pressure controller, which is mounted in the front panel of the system main frame. The automatic pressure controller allows the operator to program a desired process chamber pressure level, which is maintained by a servo-actuated throttle valve. (In systems not equipped with this option, or when the automatic pressure controller is switched OFF, the operator may move the throttle to either of two positions via toggle switches. The two positions are OPEN and CLOSED, where CLOSED means closed against a mechanical stop pre-adjusted to yield a desired pressure at a given gas flow level (typically 40 sccm at 10 milliTorr).

5.3.8 Plasma Igniter

The Plasma igniter emits an intense stream of electrons from a hot filament to ignite the plasma. When the sensor detects the absence of plasma after RF power is turned on, it activates the plasma igniter. As soon as the plasma ignites, the sensor deactivates the plasma igniter.

5.3.9 RF CONTROLS

5.3.9.1 RF Impedance Matching Networks

(See Figure 5-11.)

The impedance matching network is located in the top of the sputter head assembly. This network matches impedance of the cathode/discharge/anode (substrate table) system to the standard 50 ohm impedance of the coaxial

line, which brings power from the RF generator. Without a proper match, the RF generator cannot deliver power for the sputtering process. Instead, reflected RF travel back in the coaxial cable, causing standing waves. The result is heating of the cable. If RF reflected power continues at a high level for an extended period of time, the sputtering head and/or RF generator may be damaged.

The matching network is designed to allow independent adjustment in matching the real and imaginary parts of the impedance. A proper matching can be achieved even with wide variations in deposition parameters such as target size, target-to-substrate distance, argon pressure, etc.

Impedance matching is controlled by the LOAD and TUNE controls (see Figure 5-11, ITEMS 2 and 8).

The 4400-Series systems are supplied with RF power by a generator external to the sputtering system. The output of the generator is 50 ohms so that the power can conveniently be transmitted via a 50 ohm impedance coaxial cable. Since the impedance of the plasma within the process chamber is different from that of the cable (and may vary during the sputtering process) an electronic network, called the matching network, is located in the sputtering head Two of the components in the matching network, the load capacitor and the tuning capacitor, are adjustable to match the impedance between the output of the RF generator and the plasma.

5.3.9.2 Servo-Match™ Controller

The Servo-Match™ controller drives the motors that move these variable components in the matching network to minimize the reflected power and maximize the amount of RF energy transmitted from the RF generator (forward power).

All operator controls are located on the sputter head assembly control panel, and all electrical connections are made at the rear panel. A single printed circuit board contains the entire circuitry. All power, logic, and control signals are obtained through the control cable. A sensor box measures the phase relationship between the current and voltage in the RF cable.

The Servo-Match™ controller can be operated either manually or automatically. In the MANUAL mode, the matching impedance can be adjusted by means of the tune and load switches located on the sputter head (see TUNE switch; LOAD switch). In the AUTOMATIC mode, the controller network matches impedance automatically.

5.3.9.3 Tuning Capacitor and Motor

The tuning circuitry automatically moves the tuning capacitor to minimum reflected power by sensing the phase relationship between the voltage and current in the coaxial cable that transmits power from the generator to the sputter head. If the voltage leads the current, the controller runs the motor in one direction; if the voltage lags the current, it runs the motor in the other direction. When the voltage and current are in phase, the phase detector stops the tuning motor.

5.3.9.4 Load Capacitor and Motor

The load coil is pre-set via the potentiometers on the front panel. When a target is changed or a new operating mode is selected, the corresponding potentiometer sets the value of the load coil. The load matching circuit is driven by a position-servo system. Load matching is performed before tuning. The load matching circuit DOES NOT automatically adjust for reflected power.

5.3.9.5 RF Programmable Power/Voltage Stabilizer

The programmable power stabilizer regulates the level of RF power or voltage delivered to the selected target. It maintains constant power for RF sputtering and etching processes despite variations in AC line voltage, gas pressure, work characteristics, and temperature.

A 2-position toggle switch at the lower right front of the power/voltage stabilizer control panel allows the operator to select POWER or VOLTAGE. If POWER is selected, RF power will be maintained at the operator-preset level by automatically varying the voltage. If VOLTAGE is selected, RF voltage will be maintained by varying power.

The programmable power stabilizer operates in the MANUAL or PROGRAM modes. (MANUAL and PROGRAM modes refer to the operating mode of the MSC, which is described in Chapter 6.

Manual Mode	The power stabilizer may be either ON or OFF. When it is ON, the stabilized power adjust dial controls the RF power to the sputter head assembly. When it is OFF, the RF power is controlled manually by the RF power adjust potentiometer on the system meter panel, but no stabilization operations are performed.
Program Mode	Control of RF power is transferred to the MSC or to the RF power adjust knob on the sputter head assembly control panel.

5.3.10 Gas Metering Valves (3)

(See Figure 5-12.)

Located on the right side of the sputter head assembly, the manual gas metering assembly consists of a stainless steel needle valve equipped with a precision micrometer head for accurate and repeatable settings. (Turning the micrometer head clockwise reduces the flow of gas.) The proper setting is determined empirically and depends upon a) the desired argon pressure, and b) the adjustment of the throttle valve. On systems equipped with manual gas only, the throttle valve is factory-preset to a mechanical stop for 40 sccm at at a pressure of 10 milliTorr. (On manual gas systems, the operator can select THROTTLE OPEN or THROTTLE CLOSED [to the 10 mT/40 sccm position]).

An gas shut-off solenoid valve is connected in series with the gas metering valve. During operation, the metering valve is set to produce the desired gas working pressure, and the shut-off valve stops and starts the flow of gas without changing the metering valve setting. The shut-off valve is actuated

by the gas control on the automatic pressure controller (included with the Brooks gas control option).

The automatic gas option (which may be installed to control one (1), two (2), or three (3) gases) consists of Brooks Model 5058 flow controllers and a servo-operated throttle valve. As in manual gas systems, the throttle is factory-preset for 10 mT/40 sccm. A typical 3-gas arrangement is:

GAS 1	NITROGEN, 0 - 100 SCCM
GAS 2	NITROGEN, 0 - 10 SCCM
GAS 3	NITROGEN, 0 - 10 SCCM

The operator selects a desired pressure and flow rate for one or more gases via programmed data cards (all models, or optionally via the data terminal keyboard on Model 4480), and the throttle servos to maintain the desired chamber pressure.

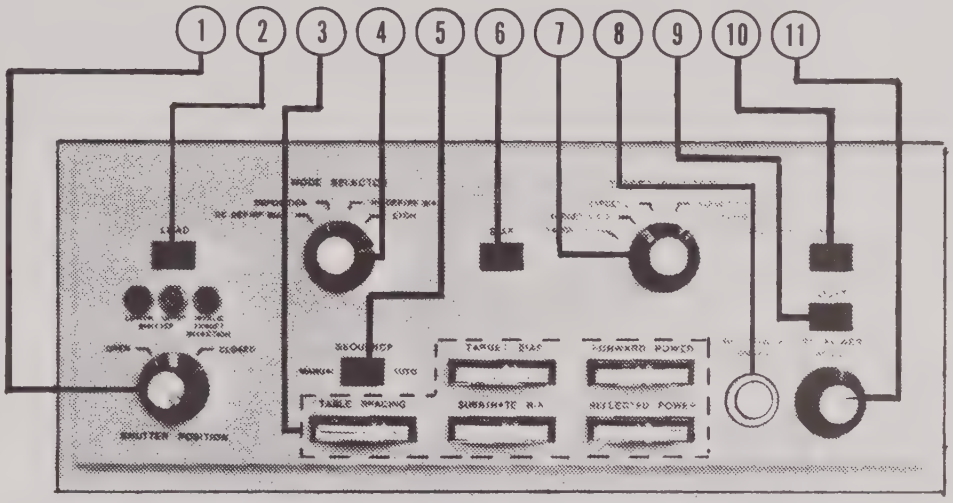


FIGURE 5-13

MODELS 4450 / 4480 SPUTTER HEAD FRONT PANEL

1. SHUTTER POSITION SELECTOR
2. LOAD TUNE SWITCH
3. ANALOG METERS
4. MODE SELECTOR SWITCH
5. SEQUENCE SWITCH
6. BIAS SWITCH
7. TARGET SELECTOR SWITCH
8. RF POWER ON / OFF PUSHBUTTON
9. LIGHT SWITCH
10. TUNE SWITCH
11. RF POWER ADJUST CONTROL

5.4 Sputtering Head Assembly - Models 4450/4480

5.4.1 Control Panel

The sputter head assembly (Models 4450/4480) includes a complete range of controls to regulate the system parameters affecting the sputtering process. Adjusting the system to produce the desired result requires a certain amount of experimentation. Some experimentation with a specific machine at various settings (using sample or reject wafers) should suffice to determine the correct settings for any given process.

The following controls and indicators are located on the control panel of the sputter head assembly (see Figure 5-13).

5.4.1.1 Shutter Position Switch [ITEM No. 1]

Allows the shutter to be closed during the sputter etch mode, and open to the selected target or targets for sputter deposition. When the sputter head front panel AUTO/MANUAL switch is in the automatic position, shutters automatically are moved to the proper position for the selected operation (i.e., CLOSED for etch and pre-sputtering, OPEN to the correct target(s) for target burn-in and sputter deposition).

5.4.1.2 Load Tune Switch [ITEM No. 2]

The load tune switch drives a motor which controls the setting for the RF load tuning circuit. It is used in conjunction with the TUNE switch. Both switches, used together, match (manually) the RF power to the load. They are overridden by the Servo-Match™ controller when the head is operated in the automatic tune mode.

5.4.1.3 Table Spacing Meter[ITEM No. 3]

Measures the distance between the substrate table and the target surface on a scale from 0" - 5".

5.4.1.4 Target Bias Meter [ITEM No. 3]

Measures the voltage applied to the target.

5.4.1.5 Substrate Bias Meter [ITEM No. 3]

Measures the voltage applied to the substrate table.

5.4.1.6 Forward Power Meter [ITEM No. 3]

Measures the total power output of the RF generator. (A 2kW meter is installed if a 2kW power supply is to be used; 3kW for a 3kW power supply.)

5.4.1.7 Reflected Power Meter [ITEM No. 3]

Measures the amount of RF power reflected back from the sputter head assembly or substrate table to the RF generator, due to impedence mismatching between the power supply and load. For best results, reflected power should be no more than 25 watts at maximum load.

5.4.1.8 Mode Selector [ITEM No. 4]

Allows selection of the following operating modes:

Sputter Deposit — [RF OR DC] RF or DC power is applied to the selected target. The substrate table is grounded. The Target Bias meter displays RF or DC power applied to the target.

Bias Sputter — [RF ONLY] Most RF power is applied to the target, but a small amount of RF power (up to 10%) can be applied to the substrate table. Consequently, substrates also are bombarded by ions, but to a much lesser degree than is the target. In many cases this technique yields higher quality deposits and better step coverage than RF sputtering with grounded substrates. Bias is read on the RF BIAS meter.

Sputter Etch — [RF ONLY] RF power (1 kW maximum) is applied to the substrate table, and material is removed (etched away) from the substrate by ion bombardment. Self-bias is displayed on the TARGET BIAS meter.

5.4.1.9 Sequence Switch - Models 4450/4480 [ITEM No. 5]

The sequence switch is used to switch load commands for manual or automatic remote operation (THE SEQUENCE SWITCH MUST BE IN THE AUTO POSITION IN ORDER TO PRODUCE AUTOMATIC SEQUENCES VIA THE MSC).

5.4.1.10 BIAS ADJUST SWITCH [ITEM No. 6]

Active only in the BIAS SPUTTER operating mode. Adjusts percentage of RF power applied to the substrate table. Varying amount of power varies negative self-bias on the table. Bias is displayed on the SUBSTRATE BIAS meter (-500V full scale). Substrate bias is normally in the range 0 - 10% of target bias.

5.4.1.11 Target Selector Switch [ITEM No. 7]

Connects output of the matching circuit to any of the THREE (3) targets and/or the substrate table. The target selector switch has five positions. In the TARGET 1 position, RF power is applied to TARGET 1 (the target on the left as viewed from the front of the system). This switch allows power to be

applied to any of the three targets separately (or using the power splitting option, to targets 1 and 3 simultaneously). TARGET 2 is the rear target. TARGET 3 is on the right. In the ETCH position, RF power is applied to the substrate table.

5.4.1.12 RF Power Switch [ITEM No. 8]

Activates the RF power supply to couple the RF power to the sputtering head assembly (or substrate table). The generator is interlocked so that power cannot be applied while the chamber is at atmosphere.

5.4.1.13 Tune Control Switch [ITEM No. 10]

The tune control switch drives a motor which controls the setting for the RF tuning capacitor. It is used in conjunction with the LOAD switch. Both switches are used together to match the RF power to the load manually. They are overridden by the Servo-Match™ controller when it is operated in the automatic tune mode.

5.4.1.14 RF Power Adjust Potentiometer [ITEM No. 11]

Governs power output from the RF power generator.

5.4.2 Cathodes

The cathode is a negatively-charged electrode, the source of the material sputtered onto the substrates. The cathode assembly consists of the target itself, a backing plate, insulators, cooling tubes, magnets (if a magnetron cathode), and the necessary electrical connections. Target materials are attached to the target backing plates using a solder-bonding technique.

Models 4450/4480 are designed to use Delta™ cathodes. The Model 4400 uses 8" round RF or DC cathodes, which may also be adapted for use with the Models 4450/4480.

Target-changing, using either Delta™ or 8" round cathodes, is a simple procedure which may be performed by the operator in only a few minutes.

5.4.3 Shutters

Shutters are disks or plates (depending on target configuration) mounted on the sputter head assembly and actuated from the sputter head assembly control panel. They are used to separate the target(s) from the substrate pallet during sputter etching, to prevent material removed from the substrates from contaminating the target(s). They also are closed for target pre-cleaning (short duration ONLY) prior to sputter deposition.

Shutters are also used to open the desired target(s) selectively to the substrates for sputtering.

5.4.4 Dark Space Shields

The dark space shield surrounds the target assembly at a distance of 1/8" from the target to prevent plasma from being generated on the sides of the targets. It focuses the discharge and provides grounding surfaces for the discharge.

5.4.5 Cross-Contamination Shields

Standard on all 4400-Series systems, these prevent material sputtered from one target from contaminating other targets.

5.4.6 Shapers

In the 4400-Series systems (using 8" round DC or RF magnetron targets), the shapers create a circular, symmetrical deposition pattern. Substrates are typically placed on the annular substrate table and rotated continuously beneath the target during deposition. Uniformity is achieved by "shaping" the vapor flux with shields (shapers) through which have been cut specially designed apertures. Shapers are always used when sputtering from 8" round targets.

Shapers are available as an option for the Model 4400.

Shapers are designed to be quickly and easily removed for replacement or cleaning whenever the process chamber is vented.

5.4.7 Brooks 1, 2, or 3 Automatic Gas Flow Controllers

(See Figure 5-12.)

Brooks automatic gas controllers are available as options for all 4400-Series systems. This option allows the operator to program desired flow levels of one or more gases into the process chamber via the MSC, as part of an automatic sequence. Brooks controllers are mounted to the right rear of the sputter head assembly, behind the manual gas flow valves.

Included as part of the Automatic gas control option is an automatic pressure controller, which is mounted in the front panel of the system main frame. The automatic pressure controller allows the operator to program a desired process chamber pressure level, which is maintained by a servo-actuated throttle valve. (In systems not equipped with this option, or when the automatic pressure controller is switched OFF, the operator may move the throttle to either of two positions via toggle switches. The two positions are OPEN and CLOSED, where CLOSED means closed against a mechanical stop pre-adjusted to yield a desired pressure at a given gas flow level (factory-preset for 40 sccm at 10 milliTorr).

5.4.8 Plasma Igniter

The Plasma igniter emits an intense stream of electrons from a hot filament to ignite the plasma. When the sensor detects the absence of plasma after RF power is turned on, it activates the plasma igniter. As soon as the plasma ignites, the sensor deactivates the plasma igniter.

5.4.9 RF CONTROLS

5.4.9.1 RF Impedance Matching Networks

(See Figure 5-13.)

The 4400-Series systems are supplied with RF power by a generator external to the sputtering system. The output of the generator is 50 ohms so that the power can conveniently be transmitted via a 50 ohm impedance coaxial cable. Since the impedance of the plasma within the process chamber is different from that of the cable (and may vary during the sputtering process) an electronic network, called the matching network, is located in the sputtering head Two of the components in the matching network, the load capacitor and the tuning capacitor, are adjustable to match the impedance between the output of the RF generator and the plasma.

The matching network is designed to allow independent adjustment in matching the real and imaginary parts of the impedance. A proper matching can be achieved even with wide variations in deposition parameters such as target size, target-to-substrate distance, argon pressure, etc.

Impedance matching is controlled by the LOAD and TUNE controls (see Figure 5-13, ITEMS 2 and 10).

5.4.9.2 Servo-Match™ Controller

The Servo-Match™ controller drives the motors that move the variable components in the matching network to minimize the reflected power and maximize the amount of RF energy transmitted from the RF generator (forward power).

All operator controls are located on the sputter head assembly control panel, and all electrical connections are made at the rear panel. A single printed circuit board contains the entire circuitry. All power, logic, and control signals are obtained through the control cable. A sensor box measures the phase relationship between the current and voltage in the RF cable.

The Servo-Match™ controller can be operated either manually or automatically. In the MANUAL mode, the matching impedance can be adjusted by means of the tune and load switches located on the sputter head (see TUNE switch; LOAD switch). In the AUTOMATIC mode, the controller network matches impedance automatically.

5.4.9.3 Tuning Capacitor and Motor

The tuning circuitry automatically moves the tuning capacitor to minimum reflected power by sensing the phase relationship between the voltage and current in the coaxial cable that transmits power from the generator to the sputter head. If the voltage leads the current, the controller runs the motor in one direction; if the voltage lags the current, it runs the motor in

the other direction. When the voltage and current are in phase, the phase detector stops the tuning motor.

5.4.9.4 Load Capacitor and Motor

The load matching circuit is pre-set via the potentiometers on the front panel. When a target is changed or a new operating mode is selected, the corresponding potentiometer must be adjusted to the value of the load matching circuit. The load matching circuit is driven by a position-servo system. Load matching is performed before tuning. The load matching circuit DOES NOT automatically adjust for reflected power.

5.4.9.5 RF Programmable Power/Voltage Stabilizer

The programmable power stabilizer regulates the level of RF power or voltage delivered to the selected target. It maintains constant power for RF sputtering and etching processes despite variations in AC line voltage, gas pressure, work characteristics, and temperature.

A 2-position toggle switch at the lower right front of the power/voltage stabilizer control panel allows the operator to select POWER or VOLTAGE. If POWER is selected, RF power will be maintained at the operator-preset level by automatically varying the voltage. If VOLTAGE is selected, RF voltage will be maintained by varying power.

The programmable power stabilizer operates in the MANUAL or PROGRAM modes. (MANUAL and PROGRAM modes refer to the operating mode of the MSC, which is described in Chapter 6.

Manual Mode	The power stabilizer may be either ON or OFF. When it is ON, the stabilized power adjust dial controls the RF power to the sputter head assembly. When it is OFF, the RF power is controlled manually by the RF power adjust potentiometer on the system meter panel, but no stabilization operations are performed.
Program Mode	Control of RF power is transferred to the MSC or to the RF power adjust knob on the sputter head assembly control panel.

5.4.10 Gas Metering Valves (3)

(See Figure 5-12.)

Located on the right side of the sputter head assembly, the manual gas metering assembly consists of a stainless steel needle valve equipped with a precision micrometer head for accurate and repeatable settings. (Turning the micrometer head clockwise reduces the flow of gas.) The proper setting is determined empirically and depends upon a) the desired argon pressure, and b) the adjustment of the throttle valve. On systems equipped with manual gas only, the throttle valve is factory-preset to a mechanical stop for 40 sccm at at a pressure of 10 milliTorr. (On manual gas systems, the operator can select THROTTLE OPEN or THROTTLE CLOSED [to the 10 mT/40 sccm position]).

An gas shut-off solenoid valve is connected in series with the gas metering valve. During operation, the metering valve is set to produce the desired gas working pressure, and the shut-off valve stops and starts the flow of gas without changing the metering valve setting. The shut-off valve is actuated by the gas control on the automatic pressure controller (included with the Brooks gas control option).

The automatic gas option (which may be installed to control one (1), two (2), or three (3) gases) consists of Brooks Model 5058 flow controllers and a servo-operated throttle valve. As in manual gas systems, the throttle is factory-preset for 10 mT/40 sccm. A typical 3-gas arrangement is:

GAS 1	NITROGEN, 0 - 100 SCCM
GAS 2	NITROGEN, 0 - 10 SCCM
GAS 3	NITROGEN, 0 - 10 SCCM

The operator selects a desired pressure and flow rate for one or more gases via programmed data cards (all models, or optionally via the data terminal keyboard on Model 4480), and the throttle servos to maintain the desired chamber pressure.

5.5 Power Supplies

WARNING

THE OPERATING VOLTAGES WITHIN THE RF GENERATOR AND DC POWER SUPPLY ARE POTENTIALLY LETHAL. OPERATIONS REQUIRING THE CONNECTION, DISCONNECTION, OR DISASSEMBLY OF RF GENERATORS MUST BE PERFORMED BY QUALIFIED ELECTRICAL TECHNICIANS, FOLLOWING THE PROCEDURES SET FORTH IN THE SERVICE MANUAL FOR THE SPUTTERING SYSTEM AND THE SERVICE MANUAL FOR THE PARTICULAR POWER SUPPLY. SUCH OPERATIONS ARE NOT THE FUNCTION OF SYSTEM OPERATORS.

4400-Series systems are typically provided with one or more of the following optional power supplies, depending on the application:

1. RF Generator, 1, 2, or 3 kW (3kW unit available only for Models 4450/4480 equipped with Delta™ cathodes.)
2. DC Magnetron, 5 or 10 kW (10kW unit available only for Models 4450/4480 equipped with Delta™ cathodes.)

NOTE

An RF generator will be required if sputter etching is to be performed, even if no RF sputter deposition will be performed. THE MAXIMUM POWER LIMIT FOR SPUTTER ETCH IS ONE (1) KW.

5.5.1 RF Generators

The RF power generators used with the 4400-Series systems include a crystal controlled exciter section and a single stage linear power amplifier. Complete overload protection and remote operation are standard features. Harmonic and other spurious radiation is reduced in accordance with FCC regulations and OSHA standards.

CAUTION

THE POWER TUBE DEVELOPS HIGH TEMPERATURES DURING OPERATION, FOR WHICH REASON THE GENERATOR MUST BE LOCATED FAR ENOUGH FROM ALL SURFACES TO ALLOW AN UNOBSTRUCTED FLOW OF COOL AIR THROUGH ITS REAR VENT. DO NOT PLACE OBJECTS ON THE VENTILATING GRILL ON TOP OF THE GENERATOR.

5.5.1.1 Specifications for RF Generators:

Operating Frequency	13.56 MHz
Frequency Stability	+/- 2 kHz
Output Impedence	52 Ohms (Standing wave ratio not to exceed 3:1. Reflected power not to exceed 25%.)
Exciter	7.8 MHz, crystal controlled oscillator with internal buffer/doubler.

5.5.1.2 Safety Interlock Switches

Safety interlock switches are provided as a standard feature of all 4400-Series sputtering systems. They ensure operator and system protection during RF and DC sputtering operations. RF and/or DC power cannot be turned ON if water flow, sputtering module cover, and power supply door interlocks are not in a safe condition. In addition, process gas must be ON, and the main power supply circuit breaker for each power supply being used must be ON.

When the circuit breaker on the RF generator is turned ON, the green pilot light above the breaker (on the front door panel of the cabinet) is lit and the cooling fan in the power supply cabinet begins operating.

CAUTION

BEFORE TURNING THE RF GENERATOR MAIN POWER CIRCUIT BREAKER ON, ADJUST THE POWER ADJUST CONTROL (LOCATED ON THE SPUTTERING MODULE FRONT PANEL) TO THE MINIMUM POWER SETTING (I.E., FULLY COUNTER CLOCKWISE). DO NOT APPLY POWER TO ANY TARGET UNTIL THE SYSTEM IS AT VACUUM (AT OR BELOW 50 MILLITORR).

After the main circuit breaker for the RF generator is turned ON, wait at least 90 seconds before applying RF power.

RF power is applied in one of two ways:

APPLYING RF POWER MANUALLY

1. Place the sequence switch (Models 4450/4480 only) in the MANUAL position.

2. Check that the TARGET SELECTOR and MODE SELECTOR switches are properly positioned for RF deposition.

3. Adjust the RF power selector dial for the desired power.

4. Depress the RF ON pushbutton located on the sputtering module front panel. (If the light in the button does not turn ON, depress the button again. If it still does not light, check the interlock circuits described above.)

NOTE

To prolong life of the power tubes, allow the generator to operate for five minutes in the RF OFF mode before switching OFF the RF generator main power circuit breaker.

5.5.2 Programmable DC Magnetron Power Supplies

The 5 and 10 kW programmable DC magnetron power supplies regulate the output power to a constant volt-amp (VA) product (10kW unit available only for Models 4450/4480 equipped with Delta™ cathodes). The VA constant is programmed into the power supply either via a) the manually operated potentiometer located on the power supply front panel, or b) a remotely controlled programming voltage source.

For 5 kW units, the design load value is 30 - 70 ohms with a current limit set at 12.9 amps; for 10 kW units it is 25 - 70 ohms with a current limit set at 20 amps.

The load resistance required to develop the rated maximum power in the 5 kW unit is 30 - 70 ohms; in the 10 kW unit it is 25 - 70 ohms. This value varies during operation.

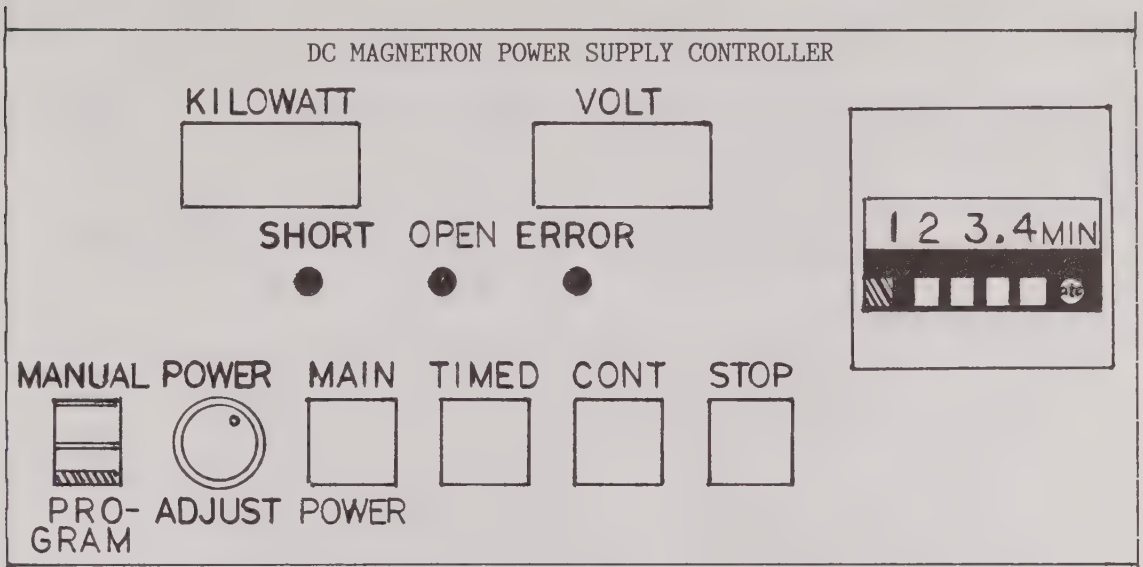
5.5.2.1 Specifications for DC Magnetron

INPUT

1. 208 VAC - 230 VAC, 3-phase, 4-wire, 60 Hz.
   200 VAC, 3-phase, 4-wire, 50 Hz.
   380 VAC, 3-phase, 4-wire, 50 Hz.
2. Connector: Arrow/Hart No. 6535, 480 V, 30 Amp.
   Mate: Arrow/Hart No. 6534.

OUTPUT

1. Current: Max. 12 Amp.
2. Voltage: Open circuit approx. 800 VDC
3. Protected for short circuits and plasma discharges.



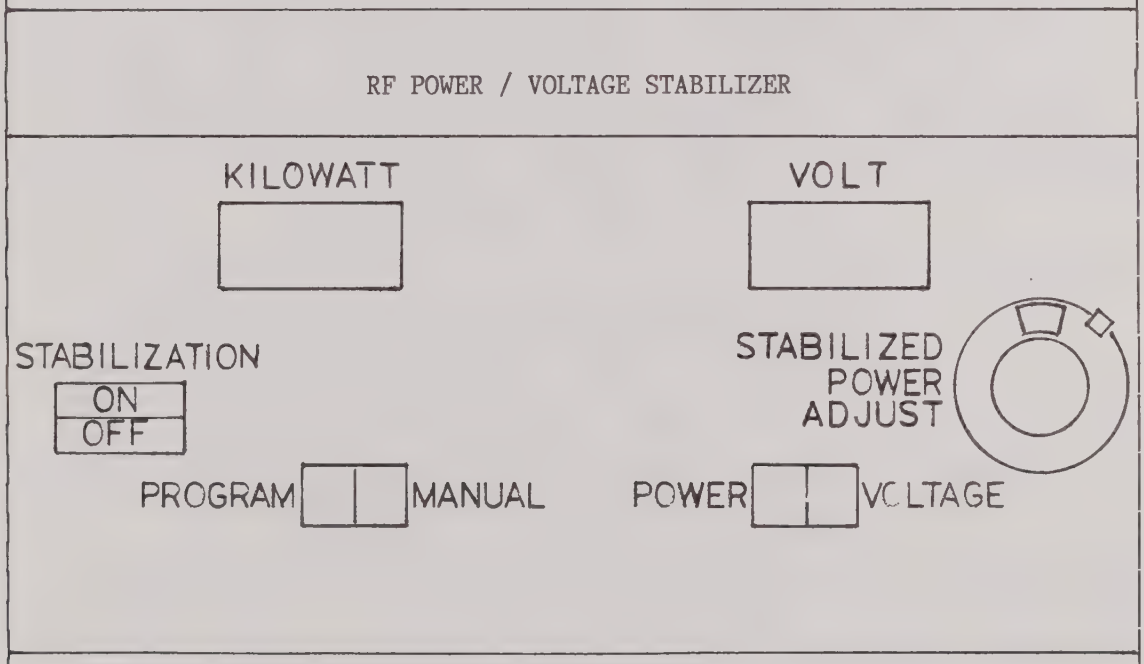


FIGURE 5-14

SYSTEM CONTROLS

METERING

1. Voltage: 0 - 1000 VDC.
2. Current: 0 - 15 Amp.

The following controls and indicators are found on the front panel of both 5 and 10 kW supplies (see Figure 5-14):

Kilowatt and Volt Digital Readouts
Display the respective levels as developed by the power supply.

Three Light Emitting Diodes
Labeled SHORT, OPEN, and ERROR, the three light emitting diodes (LEDs) provide indicators of conditions existing at output terminals of the power supply, as follows:

SHORT	Short circuit appearing across the output
OPEN	Open circuit appearing at the output
ERROR	Appears when the output VA product does not match the programmed level (manual or programmed inputs)

Digital Timer — Sets the duration of the DC deposition time. Power supply turns OFF when timer reaches zero.

MANUAL/PROGRAM Switch
Selects the operating mode of the power supply (i.e., whether the VA constant is read from the front panel potentiometer or from a remote source).

Power Adjust Knob — Sets the desired VA level (for MANUAL mode operation).

Main Power Light — Illuminates when the circuit breaker on the rear panel of the power supply is turned ON, indicating that the supply is ready for use.

TIMED Pushbutton — Initiates DC deposition and starts the timer running.

CONT[inuous] Pushbutton
Turns ON the high voltage.

STOP Pushbutton — Turns OFF high voltage.

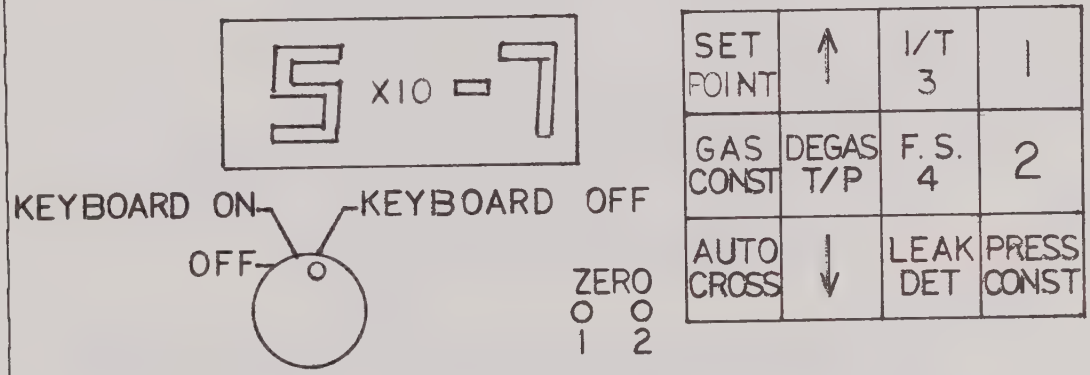


FIGURE 5-15

DGC-III DIGITAL ION GAUGE CONTROLLER

5.6 DGC-III Ion Gauge Controller

The DGC-III is used to select pressure set points, to monitor pressure via ion or thermistor tube, to automatically select an ion tube or thermistor, depending on pressure, to de-gas ion tubes, and to leak test vacuum chambers.

5.6.1 Controls and Indicators

(See Figure 5-15)

KEYBOARD / POWER KNOB
: Select power ON/OFF, keyboard ON/LOCKED. In the keyboard LOCKED mode, depressing keys has no effect. This feature is used to prevent accidental keyboard entries.

ZERO KEY
: Depressing this key resets the thermistor gauges to zero. (The ion gauges are zeroed automatically.)

COMMAND ENTRY KEYPAD
: Used to select the many special functions of the DGC-III controller. Keypad functions are described below:

Set Point
: Depressing the Set Point key takes the DGC-III out of the operating mode and prepares it to change one of the set point values. After depressing the Set Point key, depress one of the following: 1, 2, 3 (which doubles as the I/T key), or PRES CNTL, to determine if Set Point 1, 2, or 3, or the PRES CNTL set point will be adjusted.

UP and DOWN
: After the controller has been instructed which set point to adjust, as described above, the UP and DOWN keys are used to increase or decrease the value of that particular set point. Pressing the UP key momentarily, for instance, will cause the value displayed on the digital display (i.e., the value of the set point being adjusted) to INCREASE by 1/10th of a unit. Depressing and holding the UP key will cause the value to increase slowly at first, then increase rapidly. If the value is allowed to increase more than desired, it can be corrected using the DOWN key. DEPRESSING ANY KEY OTHER THAN UP OR DOWN WILL ENTER THE CHANGED VALUE INTO MEMORY, AND RETURN THE DGC-III TO NORMAL OPERATION.

I/T (Ion/Thermistor)
: Depressing this key toggles the sensing function from ion tube to thermistor tube, or from thermistor tube to ion tube. For example, if the DGC-III is monitoring Ion Gauge 2 when the I/T key is selected, it will stop monitoring that gauge and begin monitoring Thermistor Gauge 2. (IF THE SET POINT KEY HAS JUST BEEN SELECTED, THE I/T KEY WILL

FUNCTION AS A 3 (i.e., will cause the DGC-III to allow changes to the value of Set Point 3.)

1 and 2

Depressing the 1 key causes the DGC-III to begin monitoring (ion or thermistor) Gauge 1. Depressing the 2 key causes the DGC-III to begin monitoring (ion or thermistor) Gauge 2. (IF THE SET POINT KEY HAS JUST BEEN SELECTED, THE 1 AND 2 KEYS WILL INSTRUCT THE DGC-III TO ALLOW CHANGES TO THE VALUE OF SET POINT 1 OR SET POINT 2, RESPECTIVELY.)

Auto Cross

The Auto Cross function is ON if either the Gauge 1 or Gauge 2 indicator LED is flashing. Depressing the AUTO CROSS key will toggle the function (i.e., turn it ON if it was off, or OFF if it was on). When Auto Cross is ON, the DGC-III will automatically select the gauge (ion or thermistor) that is correct for the actual pressure level of the chamber in which pressure is being measured (in other words, the DGC-III will save the operator the trouble of pressing the I/T key to switch from thermistor tube to ion tube when pressure falls below 1×10^{-2} Torr, or vice versa).

Pres Cntl

Not Used.

Gas Const

The sensitivity of ion and thermistor tubes changes as the molecular composition of the vacuum environment changes. Depressing the GAS CONST key causes the DGC-III to allow changes to the Gas Constant. As soon as the GAS CONST key is depressed, the current value of the Gas Constant is displayed on the digital display. Valid Gas Constant values are 2 (hydrogen), 4 (helium), 16 (methane), 18 (water), 28 (nitrogen or air), 40 (argon), and 99 (xenon). Pressing any key OTHER than UP or DOWN enters the new Gas Constant into memory and returns the DGC-III to its normal operating mode. (The MULTIPLIER indicator LED will light whenever a Gas Constant OTHER than 28 (nitrogen) is selected.)

T/P (Torr or Pascal)

THE T/P KEY BECOMES ACTIVE ONLY WHEN THE DGC-III IS IN THE "SET GAS CONSTANT" MODE (see above). Depressing this key toggles the digital display between readings in Torr and readings in Pascal. The digital display will show an "A" for Pascal and a "C" for Torr. (The MULTIPLIER indicator LED will light whenever Pascal is selected.)

De-Gas

Depressing the DEGAS key initiates a timed de-gas procedure for the CURRENTLY SELECTED ion tube. De-gas power will be turned OFF when the counter reaches 9.9, if the operator depresses the DEGAS key a second time, or if emission current regulation fails. (The de-gas command will be rejected if no ion tube is currently ON, or if pressure exceeds 1×10^{-2} Torr.)

F.S.

Not used.

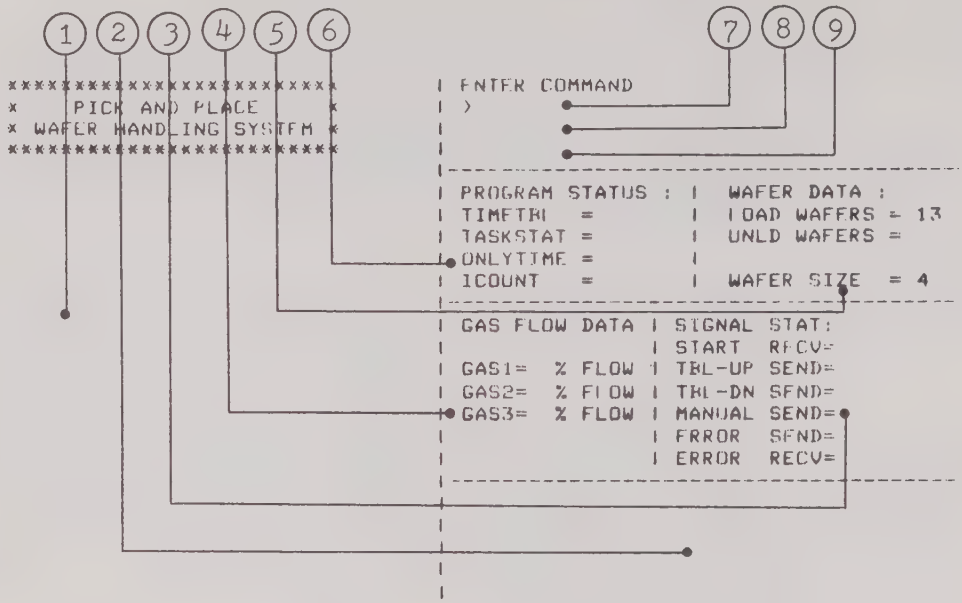


FIGURE 5-16

PE-6100 DATA TERMINAL DISPLAY (SIMULATED)

1. PICK-AND-PLACE COMMANDS AND ERROR MESSAGES
2. MSC (MAIN SYSTEM CONTROLLER) MESSAGES
3. STATUS OF COMMUNICATIONS LINES (PICK-AND-PLACE TO MSC)
4. EITHER "GAS FLOW" OR "TABLE HOME" OR "WAFER HANDLING" INFORMATION
5. WAFER SIZE, AND NUMBER OF WAFERS TO LOAD / UNLOAD DURING NEXT CYCLE
6. PROGRAM STATUS
7. COMMAND LINE (OPERATOR COMMANDS APPEAR HERE AS TYPED)
8. RESPONSE LINE (COMPUTER RESPONDS TO COMMANDS IN THIS SPACE)
9. ECHO LINE (DISPLAYS PREVIOUS OPERATOR COMMAND)

5.7 The PE-6100 Data Terminal

All 4400-Series Production Sputtering Systems are equipped with a PE-6100 Data Terminal. The CRT screen is used to display gas flow information (all systems equipped with the Brooks automatic gas control option), error messages, and wafer handling information (Model 4480 only).

Except as used with the Model 4480 Automatic Wafer Handling system (see Chapter 7), there are no provisions at this time to allow the system operator to enter data via the PE-6100 keyboard.

5.7.1 Powering Up the PE-6100 Terminal

The PE-6100 typically remains powered up so long as the sputtering system is powered up (i.e., other than for major service operations). The PE-6100 Data Terminal may be switched ON or OFF at any time without disrupting system operation, using the ON/OFF toggle switch mounted on the left side of the data terminal housing.

5.7.2 The CRT Display

Figure 5-16 shows a typical CRT display during a wafer handling routine. Notice that the screen is divided into seven (7) distinct areas, each of which contains a different type of information. Note also that one of the areas is used to display information related to three (3) different operations: wafer handling, pallet HOME position indexing, and process gas flow levels -- according to which operation is in progress.

5.8 Safety Features

5.8.1 Safety Interlock Switches

Safety interlock switches are provided as a standard feature incorporated into all systems. They ensure operator and system protection during RF and DC sputtering. If any of the interlocks are not properly activated, RF and DC power cannot be turned ON.

5.8.1.1 Sputter Module Cover Switches

All safety covers must be in place.

5.8.1.2 RF Generator Doors

Both front and rear doors must be in place and closed.

5.8.1.3 DC Power Supply Cover Panels

All side panels must be in place on the DC power supply.

5.8.2 Water Flow Switches

Adequate water flow for cooling must be provided. Water flow switches are located in the front of the system main frame, lower right side.

Water flow switches provide fail-safe monitoring of water flow in the range 0.1 - 10.0 gallons per minute (gpm). The turbine portion of the flow switch is installed in series with the outlet water line of the component being protected. Water passing through the switch housing rotates a paddle wheel, generating a voltage which is detected by the solid-state sensing module. If the voltage indicates a flow rate BELOW the pre-set value, a relay in the sensing module de-energizes, turning the protected device OFF immediately.

5.8.3 Logic Interlocks

The MSC checks for the following conditions before allowing the operator to initiate sputtering operations:

5.8.3.1 RF Power Supply Output Power

The RF power supply main power circuit breaker must be ON.

5.8.3.2 DC Power Supply Output Power

The DC power supply main power circuit breaker must be ON.

5.8.3.3 Gas Mode

The gas mode must be ON to supply sputtering gas to the process chamber.

Chapter 6

THE MAIN SYSTEM CONTROLLER - MSC

The Main System Controller (referred to throughout this manual as the MSC) is conveniently located in the upper center bay of the sputtering system main frame.

The MSC allows the operator to control system operation in three (3) ways:

1. After entering process instructions into MSC computer memory via data cards (explained in Section 6.5 of this chapter) or via the PE-6100 Data Terminal keyboard (Model 4480 only -- explained in section 7.4 of the next chapter) , the operator may initiate a complete sequence of operations simply by depressing the ENABLE and CYCLE START pushbuttons simultaneously.

2. By simultaneously depressing the ENABLE pushbutton and any other of the square shaped AUTOMATIC SEQUENCE pushbuttons (explained in Section 6.3 of this chapter), the operator may initiate a standard system function, such as pumping the process chamber to high vacuum, transferring the substrate pallet from the process chamber to the load lock, venting the system, etc.

3. By selectively positioning the MANUAL CONTROL toggle switches (explained in Chapter 8), an EXPERIENCED operator may directly control all pumping, venting, and mechanical motion functions. THE MANUAL CONTROL MODE ALLOWS THE OPERATOR TO PERFORM POTENTIALLY DANGEROUS OPERATIONS. THIS MODE IS FOR THE USE OF PROCESS ENGINEERS AND SERVICE PERSONNEL ONLY.

The Perkin-Elmer MSC is a solid state, microprocessor based unit capable of providing either automatic or manual control of the 4400-Series Production Sputtering Systems. It is equipped with a 30 step, user programmable memory designed to store process instructions. Process instructions are commands, entered into the MSC via operator-encoded data cards, which control some or all of the following system functions:

- Gas Control
- Pressure Control
- Load Lock Control
- Target Selection
- Process Mode Selection
- Deposition and Etch Voltage/Power Settings

- Deposition/Etch Time
- Pallet Loading/Unloading (*)
- Pumpdown and Vent Control (*)
- Automatic Wafer Handling (*)

The functions marked with an asterisk (*) are provided by the MSC whether or not a process sequence is entered via data cards. These functions can be initiated via a program sequence using data cards, or by depressing the ENABLE pushbutton in conjunction with the appropriate function pushbutton: UNLOAD, PUMP, VENT, etc.

NOTE

Some of the automatic functions of the MSC (i.e., automatic target selection, automatic sputtering mode selection) cannot be performed by the Model 4400, since that system's sputtering module is not designed for automatic operation.

NOTE

The MSC is programmed to control all possible system configurations, regardless of which options actually have been installed on a given system. For this reason, there may be switches on the MSC that have no application for the system being operated.

6.1 Operating the MSC

(See Figure 6-1 for locations of components.)

The MSC provides either MANUAL (all systems) or AUTOMATIC (all systems, but to varying degrees) control of the sputtering system. In the AUTOMATIC and PROGRAM modes, software interlocks protect the system from improper operation. Because no such interlocks function in the MANUAL mode, the operator must be familiar with the procedures described in this section before attempting to operate the system in the MANUAL mode.

CAUTION

BEFORE TURNING ON A.C. POWER TO THE SPUTTERING SYSTEM, CHECK THAT THE MSC IS IN THE MANUAL MODE.

6.1.1 Key Switch - MSC

The MSC can be key-locked into any of three modes: MANUAL, PROGRAM, or AUTO. During normal process operation the system should be locked in the AUTO mode. The AUTO mode keeps the current set of process instructions stored in memory, allows two-button process cycle initiation, and protects the system against illegal operations through intrinsic software interlocks. The key switch positions and the functions associated with each position are summarized in Table 6-1.

A RESET function is also provided. The RESET key switch position is spring-loaded (i.e., momentary closure).

Selecting RESET, by turning the key switch to the far left position and then releasing it, causes the MSC computer to re-initialize (i.e., to abort all operations in progress. If the carriage and/or pallet is/are not in the load lock when the RESET is performed, the operator will have to re-position them using the MANUAL mode before proceeding with another automatic sequence. If the MSC is powered down, stored process instructions will be lost; in this case, re-load data cards before proceeding.

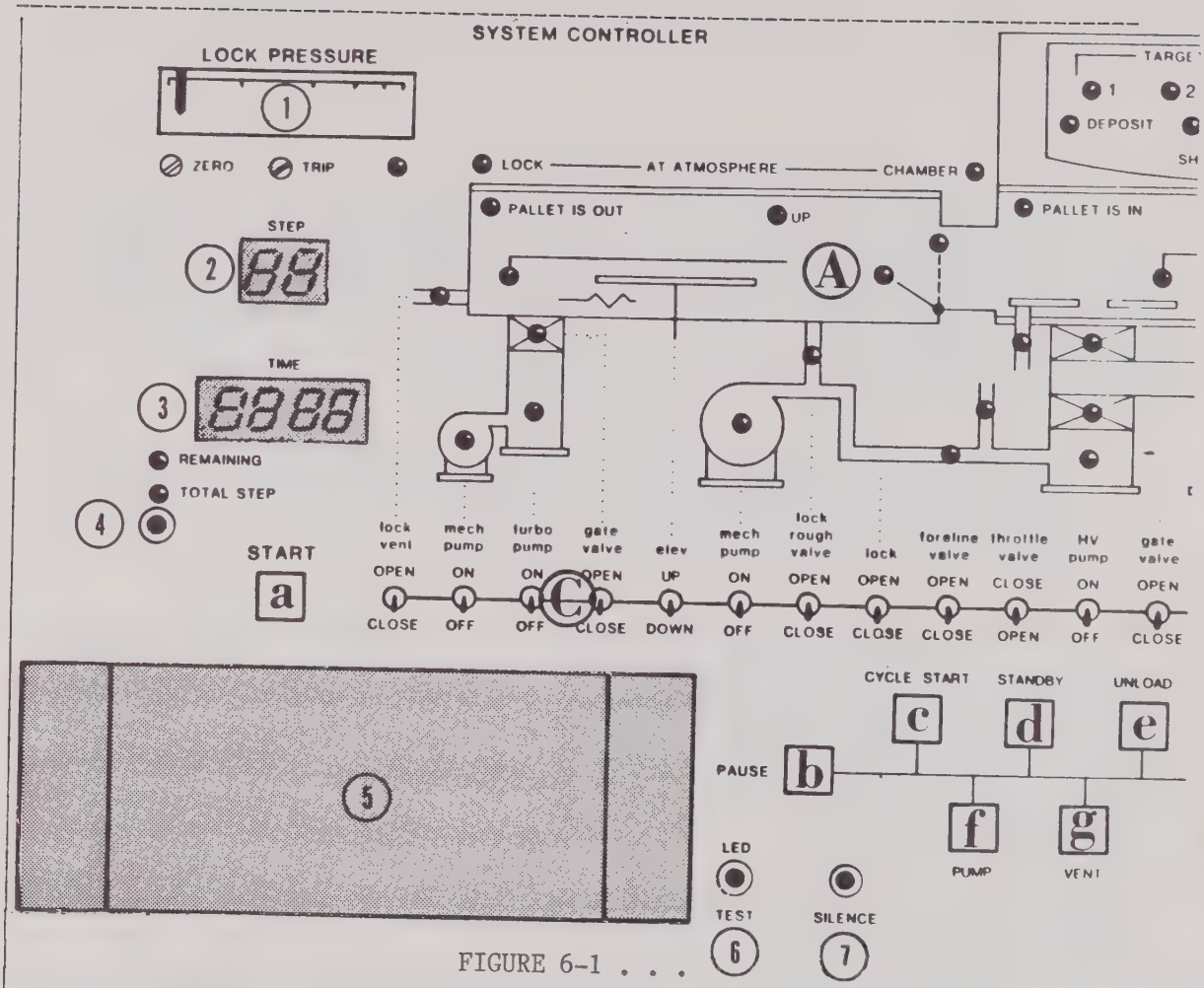
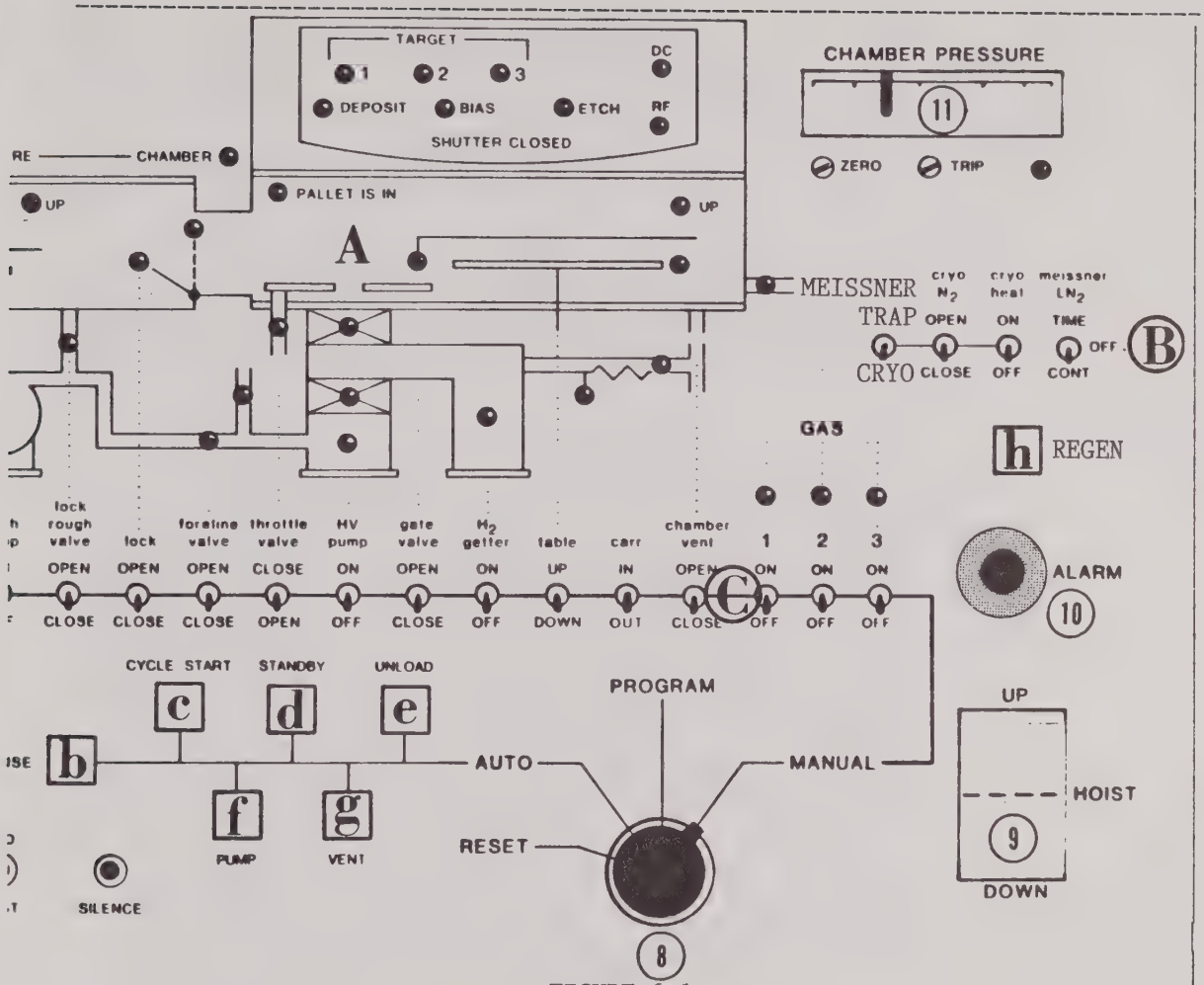


FIGURE 6-1 . . .

MAIN SYSTEM CONTROLLER FRONT PANEL

1. LOAD LOCK PRESSURE ANALOG GAUGE
2. "STEP NUMBER" DIGITAL DISPLAY
3. "TIME REMAINING" / "TOTAL TIME" DIGITAL DISPLAY
4. "TIME REMAINING" / "TOTAL TIME" SELECTOR PUSHBUTTON
5. DATA CARD READER
6. LED TEST PUSHBUTTON
7. ALARM SILENCE PUSHBUTTON
8. MODE SELECTOR KNOB
9. SPUTTERING HEAD HOIST ACTUATOR SWITCH
10. AUDIBLE ALARM TRANSDUCER
11. PROCESS CHAMBER PRESSURE ANALOG GAUGE



. . . FIGURE 6-1

MAIN SYSTEM CONTROLLER FRONT PANEL

A. SYSTEM LAYOUT WITH LED INDICATORS

B. TOGGLE SWITCHES FOR MANUAL CRYO OR MEISSNER FUNCTIONS

C. TOGGLE SWITCHES FOR MANUAL SYSTEM CONTROL

AUTOMATIC FUNCTION PUSHBUTTONS

a. ENABLE	b. PAUSE	c. CYCLE START	d. STANDBY
e. UNLOAD	f. PUMP	g. VENT	h. REGEN

TABLE 6-1
KEY SWITCH POSITIONS

Key Switch Position	Function
MANUAL	Service mode; no active interlocks. allows direct operator control of all pumping, venting, and mechanical motion system functions. (See Chapter 8 of this manual for details of MANUAL operation.)
PROGRAM	Normal mode for inputting data card programs. In the PROGRAM mode, the CYCLE START button is active. Simultaneously depressing the ENABLE and CYCLE START buttons in the PROGRAM mode causes the MSC to single-step through the current set of process instructions, allowing variables to be verified. (Data card programming instructions are given in Section 6.5 of this chapter.)
AUTO	Normal operational mode for automatic process control. A process sequence stored in memory can be initiated (once the load lock lid has been lowered) by simultaneously depressing the CYCLE START and ENABLE buttons located on the front panel of the MSC. (Chapter 7 of this manual is devoted to AUTOMATIC system operation via the MSC.)
RESET	Resets the MSC computer and aborts any operation in progress. Pallet and carriage must be repositioned in load lock manually if they are not there, before proceeding with automatic sequences.

6.2 Manual Operation

(Chapter 8 of this manual is devoted to manual system functions.)

With the exception of the gas servo and pressure control sub-systems, and regeneration of Meissner trap and cryo pump (which must be controlled automatically), most of the functions of the sputtering system can be performed when the key switch is set to the MANUAL mode. Sequences such as pumping, venting, and pallet transport can be initiated by operating the MSC toggle switches individually.

CAUTION

ONLY PROCESS ENGINEERS OR SERVICE PERSONNEL THOROUGHLY FAMILIAR WITH SPUTTERING SYSTEM OPERATION SHOULD OPERATE SYSTEMS IN THIS MODE, HOWEVER, AS THERE ARE NO ACTIVE SOFTWARE INTERLOCKS TO PROTECT SYSTEM AND OPERATOR FROM THE RESULTS OF OPERATOR ERROR.

THE FUNCTIONS OF ALL MSC TOGGLE SWITCHES ARE LISTED IN IN TABLE 6-2.

TABLE 6-2
FRONT PANEL CONTROLS

ITEM	FUNCTION
PANEL METERS	
Analog Meter	Chamber pressure reading in milliTorr.
Analog Meter	Load Lock pressure reading in milliTorr.
DIGITAL DISPLAY	
2-Digit	Step or sequence number.
4-Digit	Clock, time remaining, or total time per step (operator selectable).
POTENTIOMETERS	
Chamber Zero	Resets the meter to zero.
Chamber Trip	Selects the chamber vacuum set point.
Lock Zero	Resets the meter to zero.
Lock Trip	Selects the lock vacuum set point.
2-POSITION TOGGLE SWITCHES	
Chamber Vent	Turns ON and OFF nitrogen vent gas.
Mechanical Roughing Pump	Turns ON and OFF roughing pump.
[Process] Chamber Gate Valve	Opens and closes chamber gate valve.
Foreline/Cryo Regen Valve	Opens and closes foreline / cryo pump regeneration valve.
Meissner Trap/ Cryo [Regenerate]	Determines which regeneration cycle will be initiated when the REGEN and ENABLE pushbuttons are depressed.
Cryo N_2 Heat	Turns ON and OFF cryo pump nitrogen heater.

...TABLE 6-2 CONTINUED

High Vacuum Pump	Turns ON and OFF Hi-Vac pump.
Throttle Valve	Opens throttle valve or closes throttle valve against a pre-set stop (typically 10% open).
Process Gas 1	Turns ON and OFF process gas 1
Process Gas 2	Turns ON and OFF process gas 2
Process Gas 3	Turns ON and OFF process gas 3
Lock Mechanical Pump	Turns ON and OFF load lock mechanical roughing pump.
Lock Turbo Pump	Turns ON and OFF load lock turbomolecular pump.
Lock Gate Valve	Opens and closes load lock gate valve.
H_2 Getter Pump	Not Used.
Lock Isolation Valve	Opens and closes the lock separating the load lock and the process chamber (i.e., the lock door through which the pallet is transferred from lock to chamber).
Elevator UP/DOWN	Raises and lowers the load lock pallet elevator.
Lock Roughing Valve	Opens and closes the load lock roughing valve.
Lock Vent Valve	Opens and closes the load lock vent valve.

3-POSITION TOGGLE SWITCHES

LN2 TIMED/CONT/OFF	Controls flow of liquid nitrogen coolant to the Meissner trap. (Center switch position = OFF)
Carriage IN/OUT	Moves pallet transport carriage in and out of the process chamber. (Center switch position = NO ACTION)
Table UP/DOWN	Raises and lowers the process chamber substrate table. (Center switch position = NO ACTION)

ROCKER SWITCHES

Hoist UP/DOWN	Raises and lowers the sputter module hoist (cannot be activated if chamber is under vacuum).

MINIATURE BUTTON SWITCHES

Time Remaining/Total Step Time	Changes 4-digit display from one mode to the other.
LED Test	Causes all LED indicators to light, for testing.
Silence	Silences system audible alarm when depressed together with ENABLE.

LED INDICATORS

Chamber Vent	Lights when venting nitrogen is ON.
Mechanical Roughing Pump	Lights when roughing pump is ON.
Foreline/Cryo Regen Valve	Lights when valve is OPEN.
Cryo Vent Valve	NOT CURRENTLY USED.
Cryo N_2 Valve	Lights when valve is OPEN.
Cryo N_2 Heater	Lights when heater is ON.
Chamber Gate Valve	Lights when valve is OPEN.
Throttle Valve	Lights when valve is CLOSED.
Process Gas 1	Lights when valve is OPEN.
Process Gas 2	Lights when valve is OPEN.
Process Gas 3	Lights when valve is OPEN.
Meissner LN2	Lights when valve is OPEN.
Lock Mechanical Pump	Lights when pump is ON.

...TABLE 6-2 CONTINUED

Lock Turbo Pump	Lights when pump is ON.
Lock Gate Valve	Lights when valve is OPEN.
Chamber Hi-Vac Pump	Lights when pump is ON.
H_2 Getter	Not Used.
Lock Isolation Valve OPEN	Lights when door is OPEN.
Lock Isolation Valve CLOSED	Lights when door is CLOSED.
Table UP	Lights when chamber substrate table is UP.
Table DOWN	Lights when chamber substrate table is DOWN.
Elevator UP	Lights when load lock elevator is UP.
Elevator DOWN	Lights when load lock elevator is DOWN.
Carriage IN	Lights when pallet transport carriage is IN CHAMBER.
Carriage OUT	Lights when pallet transport carriage is IN LOAD LOCK.
Lock Roughing Valve	Lights when valve is OPEN.
Lock Vent Valve	Lights when valve is OPEN.
Lock at Atm.	Lights when lock pressure = atmospheric pressure.
Chamber at Atm.	Lights when chamber pressure = atmospheric pressure.
Lock Trip	Lights when load lock vacuum reaches set point.
Chamber Trip	Lights when load chamber vacuum reaches set point.
Pallet IN	Lights when pallet is in the process chamber. The MSC assumes pallet is OUT upon initialization (either power-up or reset). This is the "defined" starting position. The PALLET IN indicator is illuminated after the MSC performs a LOAD sequence, automatically or via manual toggle switches.

...TABLE 6-2 CONTINUED

Pallet OUT	Lights when pallet is in the load lock (see PALLET IN, above).
Target 1	Lights when Target 1 is selected via MSC output lines.
Target 2	Lights when Target 2 is selected via MSC output lines.
Target 3	Lights when Target 3 is selected via MSC output lines.
Target 4	(Model 4400 only.) Not Yet Available.
Etch	Lights during ETCH mode.
Deposit	Lights during deposit.
Bias	Lights during deposit with bias.
RF	Lights when RF power is ON.
DC	Lights when DC power is ON.
Time Remaining	Indicates that digital display shows time remaining in step.
Total Step Time	Indicates that digital display shows total step time.

AUTOMATIC SEQUENCE PUSHBUTTONS

ENABLE
CYCLE START
UNLOAD
VENT
PAUSE
STANDBY
PUMP
REGEN

_____ Explained in Section 6.3, "Automatic Operation."

END TABLE 6-2

6.3 Automatic Operation

The MSC can operate automatically when the key switch is in the AUTO position. Depressing the ENABLE and CYCLE START buttons simultaneously in the AUTO mode will initiate processing according to the current program in memory. Depressing ENABLE along with another of the AUTOMATIC SEQUENCE buttons (i.e., UNLOAD, PUMP, VENT, etc.) will initiate the desired automatic sequence.

A description of the AUTOMATIC SEQUENCE button functions follows. These functions are summarized in Table 6-3.

6.3.1 CYCLE START

The CYCLE START button is active in the AUTO and PROGRAM modes. In the AUTO mode it serves the following functions:

- MODEL 4480 USING AUTOMATIC WAFER HANDLING (Pick-and-Place switch in AUTO position)

    * Starting a process sequence, as follows: Load one empty and one full cassette into place in the cassette chamber, as described in Chapter 5. Close the cassette chamber lid. Place the key switch in the AUTO position, and simultaneously depress the ENABLE and CYCLE START buttons. The automatic wafer handling system will load the first batch of wafers onto the substrate pallet, then the wafers will be transferred to the process chamber and processed according to process instructions currently in memory, without further operator assistance.

    * Removing the substrate pallet from the process chamber following a sputter deposition or etch process (IN THE AUTOMATIC WAFER HANDLING MODE ONLY, processed substrates are retained in the process chamber under Hi-Vac until ENABLE and CYCLE START are depressed).

- MODEL 4480 USING MANUAL WAFER HANDLING (Pick-and-Place switch in MANUAL position)

    * Starting a process sequence, as follows: Load the sustrate pallet and place it in the load lock. Close the load lock lid. Place the key switch in the AUTO position, and simultaneously depress the ENABLE and CYCLE START buttons. The sequence of process instructions currently in memory will be executed, after which the pallet is tranferred to the load lock (which is then vented).

In the PROGRAM mode, it performs the following function:

- Place the key switch in the PROGRAM position, then depress the ENABLE and CYCLE START buttons simultaneously. The MSC will run through the set of process instructions currently in memory, one step at a time. At each step, the operator can check parameter values, make changes as

necessary, or simply proceed to the next step by depressing the CYCLE button once more. (During PROGRAM mode operation, the front panel of the MSC provides a visual display stepnumber and timing information.)

- The PROGRAM sequence is identical to an AUTOMATIC sequence, except that the clock timer does not count down and the MSC does not automatically proceed from step to step.

6.3.2 STANDBY

The STANDBY button has three distinct functions:

STANDBY BEFORE PROCESS

Press ENABLE, CYCLE START to initiate a process sequence. Then depress ENABLE, STANDBY. The substrate pallet will be loaded into the process chamber BUT NOT PROCESSED (i.e., the system stands by) until operator repeats the ENABLE, CYCLE START command.

LOAD LOCK PUMP

Pressing ENABLE, STANDBY with the chamber at Hi-Vac, load lock vented, and no work in progress causes the load lock to pump down to vacuum, after which the system stands by for further instructions.

STANDBY AFTER PROCESS

While the pallet is in transit from the process chamber to the load lock, depress AND HOLD the ENABLE and STANDBY buttons until the pallet comes to rest in the load lock. This will override the automatic load lock venting that usually follows an unload sequence. The pallet will therefore remain in the load lock under vacuum, while the system stands by for further instructions.

NOTE

If the ENABLE, STANDBY command is given too early or too late, the load lock may begin an unwanted vent sequence. Depressing ENABLE, STANDBY after the load lock has begun to vent will cause the vent valve to close, and the load lock to pump to vacuum (after which the system stands by for further instructions).

6.3.3 UNLOAD

CAUTION

THE UNLOAD COMMAND WILL ABORT A RUNNING PROCESS. USE THIS COMMAND WITH CARE.

Pressing the ENABLE and UNLOAD buttons simultaneously causes the pallet to be unloaded from the process chamber.

The UNLOAD command may be selected any time the pallet is STATIONARY in either the process chamber or the load lock; it overrides the current process instruction and unloads the pallet, after which the load lock is vented.

6.3.4 PUMP

Pressing ENABLE and PUMP buttons simultaneously causes the process chamber to pump down to high vacuum, after which the load lock chamber is vented.

6.3.5 VENT

Pressing the ENABLE and VENT buttons simultaneously causes the system to vent to atmosphere (load lock and process chamber), where it awaits further instructions.

WARNING

THE 4400-SERIES SYSTEMS ARE NOT DESIGNED FOR USE WITH DANGEROUS GASES SUCH AS SILANE, ARSINE, ETC. TRACES OF PROCESSING GAS ARE VENTED INTO THE ATMOSPHERE SURROUNDING THE SYSTEM WHENEVER THE SYSTEM IS VENTED.

6.3.6 PAUSE

NOTE

The PAUSE function is NOT the same as the STANDBY function. PAUSE is used to temporarily halt a process cycle, while STANDBY is used as described above, to retain the load lock and/or process chamber under vacuum following pallet unloading.

6.3.6.1 ENABLE and PAUSE

Pressing the ENABLE and PAUSE buttons simultaneously halts execution of the current process (stops all "active elements" and POWER), retains all process instructions, and leaves the software pointer at the current process step. This allows the operator to stop a process, perform tests or measurements, and resume processing. To re-start the process, depress CYCLE START and ENABLE buttons simultaneously.

6.3.6.2 PAUSE after ALARM

In the event of a system or sequence malfuntion, an alarm is sounded. If the malfuntion is a "soft error" (see the chapter on Troubleshooting), the process will PAUSE rather than ABORTing. After remedying the cause of the error, the operator re-starts the process from the beginning by simultaneously depressing the ENABLE and CYCLE START buttons (if pallet is in the load lock) or by returning the pallet to the load lock manually (if pallet is not already there).

TABLE 6-3
FUNCTIONS OF AUTOMATIC SEQUENCE PUSHBUTTONS

CONTROL SWITCH	FUNCTION
ENABLE/CYCLE START (AUTO)	Begins with pallet loaded (load lock at atmospheric pressure) and chamber at vacuum. Initiates current instruction set.
ENABLE/CYCLE START (PROGRAM)	Allows for visual check of sequence by permitting "single-stepping" through the instruction set.
ENABLE/STANDBY	Actuated before an instruction set is initiated, causes the load lock to pump to vacuum and system to await further instructions. Actuated after CYCLE START, causes pallet to remain under vacuum inthe process chamber after processing, after which the system awaits further instructions. Actuated after UNLOAD, causes pallet to remain under vacuum in load lock and system to await further instructions.
ENABLE/UNLOAD	Causes pallet to be unloaded from process chamber and sent to load lock. Overrides any ongoing process cycle.
ENABLE/PUMP	Pumps process chamber to high vacuum from atmosphere, and vents load lock to atmosphere.
ENABLE/VENT	Vents process chamber and load lock to atmosphere.
PAUSE (ALARM)	Indicates system or process malfuntion by sounding an audible alarm and lighting the PAUSE button. Silence alarm by depressing the ENABLE and SILENCE buttons simultaneously. Re-start process by depressing CYCLE START and ENABLE buttons simultaneously (after condition has been cleared and system returned to the ready state, with pallet in the load lock).
ENABLE/PAUSE	Halts process execution WITHOUT power. Re-start process by depressing CYCLE START and ENABLE buttons simultaneously.

In the AUTO mode, some functions CANNOT be initiated while a process cycle is being executed. Table 6-4 summarizes functions as (A) active during process execution, (I) inactive during process execution, or (N/A) inapplicable, since funtion is already implemented.

TABLE 6-4
ACTIVE AND INACTIVE FUNCTIONS DURING PROCESS CYCLE

CYCLE IN PROCESS	CAN INITIATE ___ FUNCTION?						
	CYCLE START	UNLOAD	STANDBY	PAUSE ALARM	PUMP	VENT	PROCESS INSTRUCTIONS
CYCLE START	N/A	A	A	A	I	I	A
UNLOAD	I	N/A	A	A	I	I	I
STANDBY	A	A	N/A	I	I	A	I
PAUSE ALARM	A	A	I	N/A	I	I	A
PUMP	I	I	I	I	N/A	A	I
VENT	I	I	I	I	A	N/A	I

6.4 Programmed System Operation

Setting the key switch to the PROGRAM position permits instructions to be loaded via the data card reader (see section on Data Cards, below).

6.4.1 Setting Parameters

In the program mode, the ENABLE and CYCLE START buttons are depressed simultaneously to send to the MSC the first process step. At this time, all parameters associated with the first step can be verified. To advance each subsequent step to the MSC, depress the ENABLE and CYCLE START buttons again. Check the front panel display each time to verify proper program execution via the step number, time, and subsystems accessed by each program step.

6.4.2 Running the Process

Once a program has been loaded from the PROGRAM mode, place the key switch in the AUTO position. Depressing ENABLE and CYCLE START buttons simultaneously will execute the instruction set in current memory.

NOTE

Initiating any automatic sequence requires that the ENABLE button be depressed simultaneously with the appropriate FUNCTION button.

6.5 Programming the MSC

The MSC is designed to provide fully automatic operation of 4400-Series systems via three types of programs:

1. Those which are intrinsic to the MSC (i.e., the system software). These programs are stored on PROMs and control the operation of the MSC itself.

2. Those which are operator selectable via pushbuttons: CYCLE START, STANDBY, UNLOAD, PUMP, VENT,and PAUSE.

3. Those which are individually programmed by the operator. The MSC follows these specific instructions when controlling a sputtering process. Process instructions may be stored for future use on data cards. Process instructions include STANDBY, ETCH, TARGET PRE-CLEAN, SPUTTER DEPOSIT, BIAS DEPOSIT, LOAD LOCK HEAT, CHAMBER HEAT, and REPEAT.

The programs in group 1 are resident on PROMs, and comprise the internal instructions that govern the interaction between the MSC and the rest of the sputtering system. They provide the foundation for monitoring and controlling all phases of system operation so that the operator need not be concerned with the minute details of running the system. The only way a user can affect these programs is to remove and replace existing PROMs.

The programs in group 2 are the FUNCTIONS initiated by depressing the ENABLE button in conjunction with another FUNCTION button. These programs cannot be modified by editing or by inputting new information.

Descriptions of the group 2 functions and instructions for their use are given in the preceding section.

The programs in group 3 are referred to, throughout this manual, as PROCESS INSTRUCTIONS, to avoid confusion between these user-programmable functions and other, non-user-programmable ones. Process instructions are entered via data cards (see Figure 6-2), which are programmed by punching holes in the card with a suitable device. (Punched holes must be exactly one-quarter ince (1/4") in diameter.)

NOTE

Process instructions may alternatively be entered via the PE-6100 Data Terminal keyboard (Model 4480 only). Instructions for keyboard entry of process instructions are given in Section 7.4.

A set of instructions from a single data card is referred to as a PROCESS STEP. Each data card (and consequently, each process instruction) is assigned a STEP NUMBER. Data cards may be fed into the data card reader in any order; the computer arranges the process instructions in the correct order based on the step number programmed onto each card. If two cards bear the same step number, the one entered LAST will override the prior instruction.

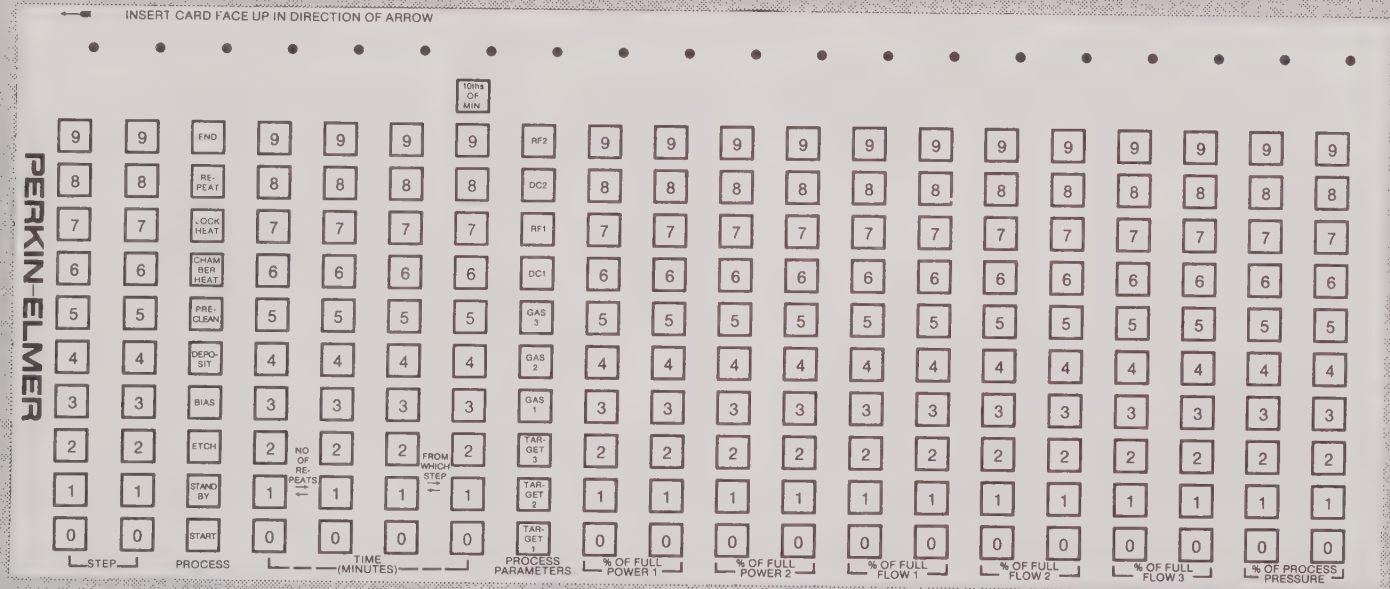


FIGURE 6-2

PROGRAMMABLE DATA CARD

PUNCH ONE-QUARTER INCH (1/4") HOLE IN APPROPRIATE BOXES
USE ONE DATA CARD FOR EACH PROCESS STEP

The card reader is mechanical in operation: the user supplies the motive force by feeding the card into the slot at the top of the reader and grasping it as it emerges at the bottom to pull it through in a smooth, continuous motion. Data will be accepted properly if cards are fed into the reader with the printed side toward the operator, and with the row of evenly-spaced timing holes toward the left edge of the card reader.

The MSC interprets process instructions using the body of information contained in the group 1 programs. For example, when an operator instructs the MSC to perform an ETCH function, it is not necessary to tell the MSC how an ETCH is performed. All of this necessary information is pre-programmed into the system.

The operator creates a string of process steps (sequentially numbered), each of which is a PROCESS: ENABLE, STANDBY, ETCH, BIAS, DEPOSIT, PRE-CLEAN, CHAMBER HEAT, LOCK HEAT, REPEAT, END. The MSC asks the operator to assign values for some PROCESS PARAMETERS (e.g., a percentage of total power to apply during DC sputtering, duration of a process, type and flow rate of sputtering gas, etc.).

IF ANY FIELD REQUIRING A NUMERICAL ENTRY IS NOT USED, THAT FIELD SHOULD BE "NULLED" WITH A "00" ENTRY.

6.5.1 User Programmable Processes

6.5.1.1 The START Process

Not yet available. Will allow the operator to start a cycle from a step other than STEP 1.

6.5.1.2 The STANDBY Process

The STANDBY instruction is typically included in a process program when the user wishes to halt process sequence temporarily without terminating it. While the operation is in the STANDBY mode, the operator may choose to continue process gas flow or to terminate gas flow and have the Hi-Vac pump continue pumping the process chamber.

The following parameters must be assigned values when programming a STANDBY step:

- Step Number
- Standby mode
- Gas Selection (if no gas is selected, PUMPING mode is default condition)
- Duration

6.5.1.3 The ETCH Process

In the ETCH mode, the shutters are closed and power is applied to the

substrates to prepare the surface for subsequent deposition.

The following parameters must be assigned values when programming a ETCH step:

- Step Number
- Etch Mode
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]
- Duration
- Power Level(s)

6.5.1.4 The DEPOSIT Process

In the DEPOSIT mode, material from one or two targets is deposited upon the substrates.

Sputter deposition requires that values be entered for all six parameters:

- Step Number
- Deposit Mode
- Target Selection [select manually for Model 4400]. Operators of Model 4450/4480 systems may select one or two targets from which to deposit material.
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]. Depending on the power source for the selected target, punch either "DC1" or "RF 1." If a second target is to be used simultaneously, punch either "DC 2" or "RF 2," and the power source for which the second target has been custom-strapped.
- Duration
- Power Level(s)

6.5.1.5 The BIAS Process

The BIAS instruction is selected if RF bias sputtering is desired. In this case, the RF power will be applied to the substrate table while either DC or RF power is applied to the selected target(s).

6.5.1.6 The PRE-CLEAN Process

In the PRE-CLEAN mode, the shutters are closed to protect the substrates.

The following parameters must be assigned values when programming a PRE-CLEAN step:

- Step Number
- Pre-Clean Mode
- Target Selection [select manually for Model 4400]
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]
- Duration
- Power Level(s)

NOTE

The pre-clean mode may be used before sputter deposition ONLY IF THE TARGET IS NOT NEW OR BADLY CONTAMINATED. For more thorough cleaning, use the burn-in procedure described in Chapter 1.

6.5.1.7 The CHAMBER HEAT Process

Selectable only on systems equipped with the in-process heater option, a CHAMBER HEAT command turns ON the radiant heater mounted in the process chamber for a specified period of time.

The following parameters must be assigned values when programming a CHAMBER HEAT step:

- Step Number
- Chamber Heat Mode
- Target Select
- Duration

NOTE

If table rotation is also desired, select any gas at "00" percent flow.

6.5.1.8 The LOCK HEAT Process

Selectable only on systems equipped with the load lock heater option, a LOCK HEAT command turns ON the radiant heater mounted in the load lock for a specified period of time.

The following parameters must be assigned values when programming a LOCK HEAT step:

- Lock Heat Mode (must be the first step)
- Step Number
- Duration

6.5.1.9 The REPEAT Process

The REPEAT instruction tells the MSC to perform a given set of steps within the process sequence a specified number of times. The operator must specify: FROM which step to begin repeating and NUMBER of repeats. For example: The REPEAT instruction appears on the data card numbered STEP 15, and calls for 4 repeats starting at STEP 10. When the process sequence is initiated, steps 1 through 14 will be performed, after which step 15 will cause steps 10, 11, 12, 13, and 14 to be performed an ADDITIONAL four (4) times.

6.5.1.10 The END Process

The END instruction terminates a sputtering process. If the system is a Model 4480 with the automatic wafer handling system in the AUTOMATIC mode, the pallet remains in the process chamber until the operator enters the ENABLE/CYCLE START command. If the system is not equipped with automatic wafer handling, or is equipped with but is not currently using automatic wafer handling, the pallet will be UNLOADED into the load lock, which is then vented to atmosphere.

No additional parameters need be specified for an END step, although all unused parameters should be "nulled" with zeroes.

Chapter 7

Automatic Wafer Handling - Model 4480 Only

NOTE

The terms MANUAL and AUTOMATIC, as used in the section covering Automatic Wafer Handling, refers ONLY to the operation of the wafer handling package. For example, it is possible to have wafer processed automatically, according to stored Process Instructions, even though loading is accomplished from the MANUAL mode.

Automatic Wafer Handling is a standard feature of the Model 4480; it may be retrofitted to the Model 4450. Using the Automatic Wafer Handling feature improves both system through-put and yield, as follows:

- While the system is loading and unloading wafers, the operator is free to perform other tasks; one operator can oversee the operation of several systems.

- Under normal operating circumstances, the substrate pallet is never exposed to atmosphere, and can remain at elevated temperature and free from atmospheric contaminants.

- Wafer contact with the PICK AND PLACE arm is designed to minimize the wafer surface damage which can occur when wafers are handled with tweezers.

- The microprocessor controlled wafer handling sequence insures accurate, repeatable processing.

- Programmed safety checks prevent damage to the mechanical assemblies resulting from operator error.

The wafer handling system is composed of two major mechanical assemblies (see Figure 6-1).

1. THE LOADING/UNLOADING SYSTEM is located in the cassette chamber and includes cassette elevators, wafer tracks, PICK AND PLACE arm, and

2. THE ROTATING TABLE, located in the Sputtering System load lock.

Wafer handling system electronics are located within the frame of the wafer handling module, and include the microprocessor; power supplies; and controllers for driving the cassette elevators, wafer tracks, PICK AND PLACE arm, and rotating table.

The wafer handling system communicates with the Main Sputtering System via

the MSC.

The AUTO/MANUAL switch on the front panel of the cassette chamber controls the wafer handling system's mode of operation. The computer is programmed to configure a specific STARTING POSITION for whichever mode is selected.

In the MANUAL mode, the AUTOMATIC wafer handling system is disabled. Wafer loading is performed by hand via the load lock (as in 4400 and 4450 systems).

In the AUTO mode, the operator places a cassette containing wafers on the SEND elevator, an empty cassette on the RECEIVE elevator, lowers the cassette chamber cover, and presses the START and CYCLE START buttons located on the MSC.

7.1 Overview of Wafer Handling - MANUAL mode

(See Figure 7-1 for locations of components.)

Before "releasing" the system to the MANUAL mode, the wafer handling computer performs the following functions:

1. The wafer handling system computer monitors the AUTO/MANUAL switch located on the cassette chamber front panel, and the START signal from the MSC. (Monitoring continues throughout the sequence.)

2. The computer checks the status of the optical wafer sensor located on the SEND elevator. If a wafer is present in the SEND cassette, an error alarm will be sounded and motion halted until the operator removes the filled SEND cassette. (For more information on Error Handling, see Chapter 10.)

3. The PICK AND PLACE arm is moved to the PARK position (clear of the substrate pallet).

4. The substrate pallet may now be loaded and unloaded by hand.

During MANUAL operation the cassette chamber/load lock is not vented to atmosphere with dry nitrogen during the deposition process, as there will be no manipulation of the SEND and RECEIVE area.

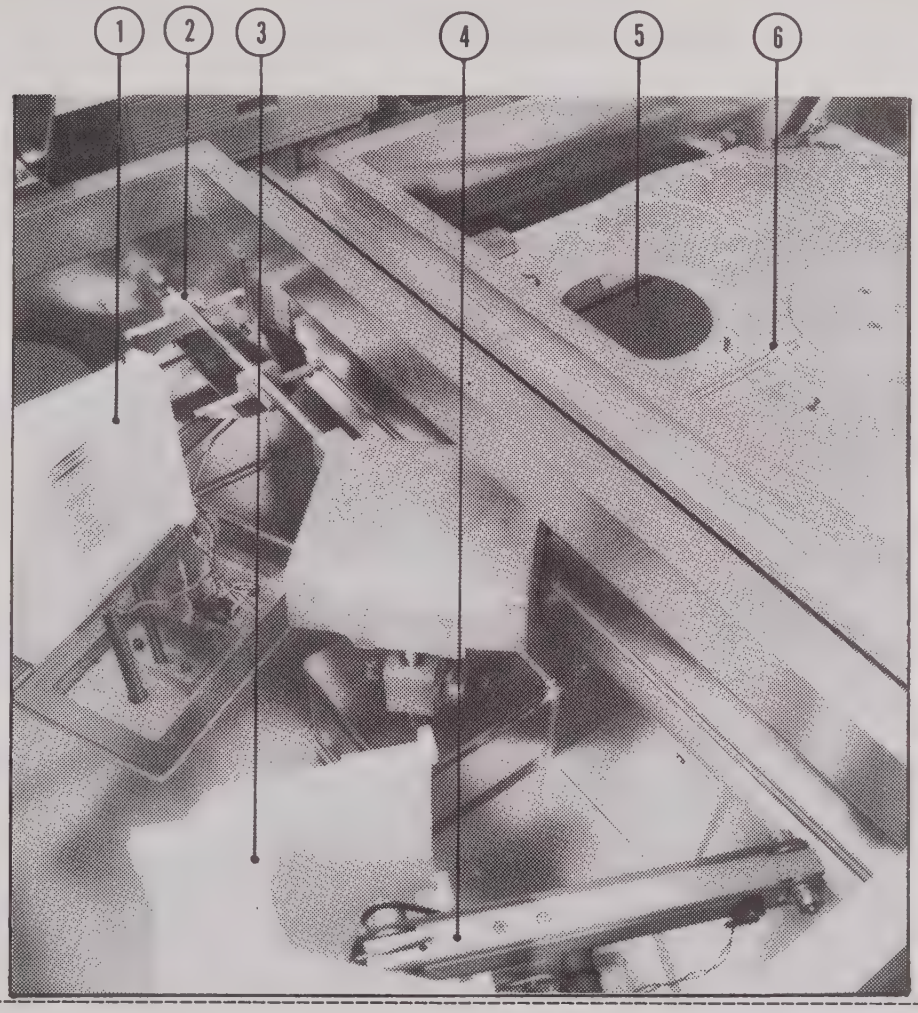


FIGURE 7-1

THE "PICK-AND-PLACE" MECHANISM

1. "SEND" CASSETTE ON "SEND" ELEVATOR.
2. WAFER ARM, WITH CLAW OPEN, POSITIONED OVER WAFER ON "SEND" TRACK.
3. "RECEIVE" CASSETTE ON "RECEIVE" ELEVATOR.
4. "RECEIVE" TRACK.
5. WAFER PREVIOUSLY PLACED ON PALLET, AFTER PALLET HAS ROTATED ONE (1) POSITION.
6. WAFER ARM OVER "HOME" POSITION. (IN AN UNLOAD SEQUENCE, THIS ARM WOULD MOVE A PROCESSED WAFER FROM "HOME" TO "RECEIVE" TRACK.

7.2 Overview of Wafer Handling - AUTOMATIC Mode

(See Figure 7-1 for locations of components)

In the AUTOMATIC mode, the wafer handling system uses standard cassettes and will accept either four inch (100mm) or five inch (125mm) wafers. A maximum of 13 4" (100mm) or 10 5" (125mm) wafers may be loaded from a cassette and processed at one time. Since loading and unloading operations are performed simultaneously by the PICK AND PLACE arm, the loading/unloading operation will continue so long as wafers remain either to be loaded or unloaded.

A typical wafer handling sequence in the AUTOMATIC mode (transfer of wafers from the SEND cassette, through processing, and back to the RECEIVE cassette) proceeds as follows:

1. The wafer handling system computer monitors the AUTO/MANUAL switch located on the cassette chamber front panel, and the START signal from the MSC. (Monitoring continues throughout the sequence.)

2. The PICK AND PLACE moves to the LOAD position. (In the LOAD position, one claw of the PICK AND PLACE arm is above the PICK position of the SEND track and the second claw is above the PLACE position of the pallet.)

3. The substrate pallet is rotated until the homing indicator senses the HOME notch on the pallet. (The HOME position is the pocket directly to the right or to the left of the notch, depending on the direction of rotation. If the pallet is rotating counter clockwise, the HOME position is to the RIGHT of the notch. If the pallet is rotating clockwise, the HOME position is to the LEFT of the notch.) The pallet stops with the HOME position co-incident with the PLACE position.

4. Both SEND and RECEIVE elevators are "zeroed" (raised to maximum vertical position).

5. The RECEIVE elevator is lowered until the first (i.e., highest) empty slot is level with the RECEIVE track.

6. The SEND elevator is lowered until the optical sensor detects the first (i.e., lowest) wafer. The SEND elevator halts with the first wafer resting upon the SEND track.

7. The SEND track belt motors are activated, withdrawing the first wafer from the SEND cassette.

8. The SEND track belt motors are de-activated when the optical sensor signals that the wafer is in the PICK position.

9. The SEND elevator is lowered until the next wafer rests upon the SEND track.

10. Both PICK AND PLACE claws open, and the arm is lowered until one claw

is in position to grasp the wafer in the PICK position. (In the lowered position described above, the second claw is in position to grasp a processed wafer from the pallet, should one be there.)

11. Both claws are closed, grasping the wafer in the PICK position of the SEND track and the processed wafer on the pallet, if any.

12. The PICK AND PLACE arm is raised and rotated 90 degrees to the UNLOAD position.

13. The PICK AND PLACE arm is lowered and both claws opened, placing the wafer from the PLACE position of the pallet (if any) on the RECEIVE track, and the wafer from the PICK position on the PLACE position of the pallet.

14. The PICK AND PLACE arm is raised and rotated 90 degrees to the LOAD position.

15. The substrate pallet is indexed to the next position.

16. If a wafer was placed on the RECEIVE track, the RECEIVE track motors are activated, moving the processed wafer into the waiting slot of the RECEIVE cassette.

17. When the processed wafer is sensed in the RECEIVE cassette, the RECEIVE track motors are de-activated and the RECEIVE cassette indexed upward one position, so the next empty slot is in position to receive a processed wafer.

18. Up to 13 4" (100mm) or 10 5" (125mm) wafers are loaded onto the substrate pallet as described above, and the processed wafers on the substrate pallet are simultaneously unloaded and placed in the RECEIVE cassette. (If there are not sufficient empty slots in the RECEIVE cassette to accept the processed wafers on the substrate pallet, an error alarm will be sounded and motion halted until the filled RECEIVE cassette is replaced with an empty one. For more information on Error Handling, see Chapter 10.)

19. After all wafers have been loaded/unloaded, the rotating table elevator is lowered, placing the substrate pallet on the transfer mechanism.

20. The TABLE DOWN sensor signals the MSC that the PICK AND PLACE operation is complete.

21. The wafer handling computer enters the MONITOR mode (i.e., monitoring both the AUTO/MANUAL switch and the signal line from the MSC.

22. To continue the operation, the operator must simultaneously press the START and CYCLE START buttons located on the MSC.

23. The load lock isolation valve, isolating the process chamber from the load lock/cassette chambers, is opened.

24. The pallet is transferred into the process chamber.

25. The load lock isolation valve is closed.

26. While the pallet is in process, the operator may open the cassette chamber. At this time, the operator typically removes a filled cassette from the RECEIVE elevator, takes the empty cassette from the SEND elevator and places it on the RECEIVE elevator, and places a cassette of wafers to be processed on the SEND elevator.

The STARTING POSITION (i.e., position of system components during the MONITOR mode) is as follows:

- Wafer pallet in the load lock
- Rotating table elevator in the lowered position
- Process chamber under vacuum

7.2.1 Loading the First Batch - AUTOMATIC mode

The operator places a standard 25-wafer cassette (containing at least 1 and as many as 25 wafers, but usually containing 13 4" (100mm) or 10 5" (125mm) wafers) on the SEND elevator, and an empty cassette on the RECEIVE elevator. (The load lock lid must be CLOSED.) After closing the cassette chamber cover, the operator simultaneously presses the START and CYCLE START buttons located on the MSC panel, initiating the wafer handling sequence.

The first group of wafers is loaded onto the substrate pallet by the PICK AND PLACE mechanism, and the loaded pallet is transferred automatically into the process chamber.

During the deposition process, the cassette chamber/load lock is vented to atmospheric pressure with dry nitrogen. After the cassette chamber/load lock is vented, the operator must again press the START and CYCLE START buttons on the MSC to continue the cycle.

7.2.2 Loading Subsequent Batches - AUTOMATIC mode

When the cassette chamber/load lock is vented, the operator replaces the SEND cassette (as it becomes empty) and/or the RECEIVE cassette (as it becomes full, or if it contains fewer empty slots than there are wafers in the batch in process).

After replacing the appropriate cassette(s) and lowering the cassette chamber cover, the operator presses the START and CYCLE START buttons located on the MSC.

It should be understood that LOAD and UNLOAD sequences are inseparable; the construction of the PICK AND PLACE arm is such that and UNLOAD motion always precedes a LOAD motion, whether or not processed wafers are present on the substrate pallet.

The loading/unloading process continues, following deposition, so long as both the wafer and load lock chambers are CLOSED and UNDER VACUUM.

NOTE

A system configured for 4" (100mm) wafers will attempt to load 13

wafers per cycle unless the operator specifies a different number of wafers by entering, from the PICK AND PLACE computer console, the command "WFLD=nn," where "nn" is a two digit number in the series 00, 01, 02,...,13. In other words, the default value of the variable WFLD is 13 for systems factory programmed for 4" (100mm) wafers.

To change the default value of WFLD from 13 to 10 (i.e., when processing 5" (125mm) wafers), enter the command "SIZE=5."

7.2.3 Unloading the Last Batch - AUTOMATIC mode

If the batch of wafers currently on the substrate pallet is to be the LAST batch, the operator leaves an empty cassette on both SEND and RECEIVE elevators, lowers the cassette chamber cover, and presses the START and CYCLE START buttons located on the MSC.

After being processed, the last batch of wafers is placed in the RECEIVE cassette. The wafer sensing mechanism on the SEND elevator determines that no wafers are waiting to be processed, so the system enters the WAIT mode, which continues indefinitely.

NOTE

The system may also be instructed to end an automatic wafer loading sequence by entering the command "WFLD=0," which instructs the system to load zero wafers. In this case, wafers in process are unloaded normally, as above, and the system enters the WAIT mode.

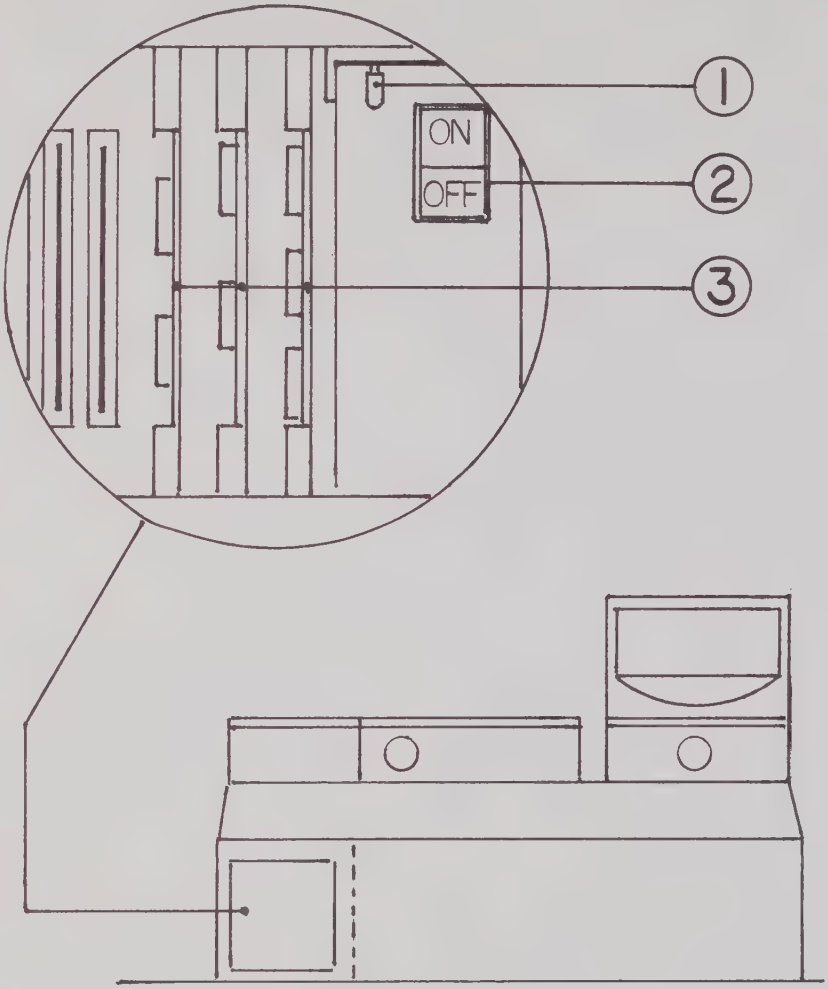


FIGURE 7-2

THE "PICK-AND-PLACE" COMPUTER

1. "RESET" PUSHBUTTON
2. COMPUTER ON / OFF ROCKER SWITCH
3. COMPUTER PRINTED CIRCUIT CARDS

7.3 Using the Computer Console

The operator enters commands to the PICK AND PLACE computer via the Perkin-Elmer Model PE-6100 terminal. The PE-6100 terminal is used to display information from both the automatic wafer handling system and the MSC.

7.3.1 Powering Up the Pick-and-Place Computer

(See Figure 7-2.)

The PE-6100 typically remains powered up so long as the sputtering system is powered up (i.e., other than for major service operations). The terminal itself is switched ON and OFF via a rocker switch located on the lower right front of the data screen enclosure. When initially powering up the sputtering system, however, it is necessary to power up and reset the PICK AND PLACE computer, as follows:

1. Check that the sputtering system is ON and functioning normally.

2. Unscrew the two (2) screws fastening the front panel of the PICK AND PLACE computer (i.e., the lower front panel of the Automatic Wafer Handling module).

3. The panel is hinged along the lower edge. Swing the panel downward to reveal an ON/OFF rocker switch at the right side of the card cage.

4. Move the rocker switch to the ON position. (The switch will light when in the ON position.)

5. A RESET button is located above the rocker switch. Press the RESET button in the upward direction to reset the terminal.

6. The CRT will begin to display information as soon as the RESET button is depressed. YOU HAVE FIVE (5) SECONDS TO ENTER THE COMMAND "CL" AND PLACE THE COMPUTER IN A "WAIT" MODE. After five (5) seconds (if the CL command is not entered) the computer will proceed with the INITIALIZATION routine (see following subsection).

7. Close the terminal front panel and tighten the two (2) fastening screws.

7.3.2 The INITIALIZATION Routine

CAUTION

IF THE "RESET" BUTTON IS DEPRESSED WHILE PICK-AND-PLACE HARDWARE IS IN MOTION, ALL MOTION WILL HALT IMMEDIATELY (WHEREAS THE "CL" COMMAND HALTS MOTION AFTER THE MOTION IN PROGRESS IS COMPLETE). IT IS POSSIBLE FOR A MECHANICAL COMPONENT TO HALT BETWEEN SENSOR POSITIONS. THE SYSTEM WILL NOT SUBSEQUENTLY BE ABLE TO COMPLETE

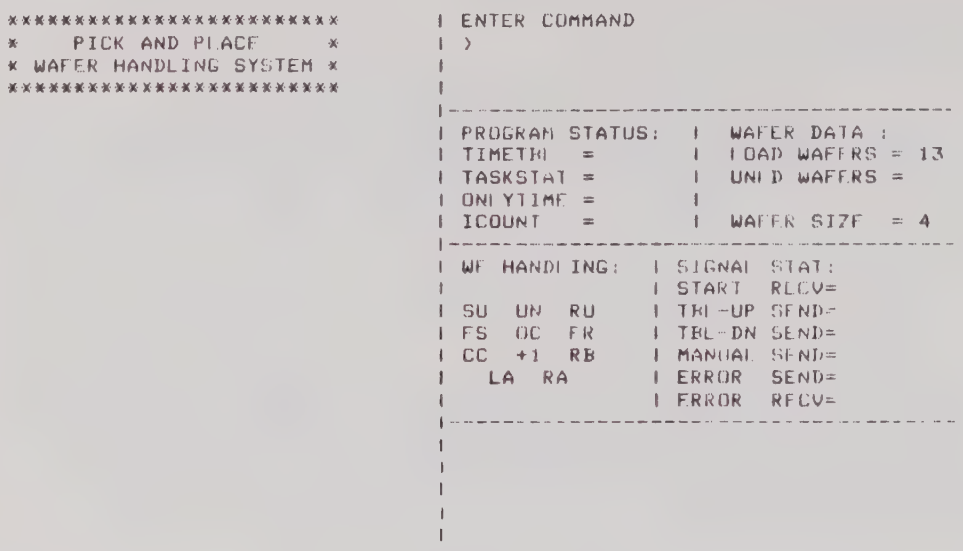


FIGURE 7-3

PE-6100 DATA TERMINAL DISPLAY (SIMULATED)

"PICK-AND-PLACE" INFORMATION IS DISPLAYED ONLY ON MODEL 4480.

GAS FLOW INFORMATION IS DISPLAYED ONLY ON SYSTEMS EQUIPPED WITH THE AUTOMATIC GAS CONTROL OPTION.

ITS INITIALIZATION ROUTINE, AND IT WILL BE NECESSARY TO OPEN THE SYSTEM SIDE PANELS TO RESTORE COMPONENTS TO A VALID STARTING POSITION BY HAND. IT IS BETTER TO USE THE "CL" COMMAND EXCEPT IN THOSE EMERGENCIES WHEN IT IS NECESSARY TO HALT MOTION IMMEDIATELY.

NOTE

A "CL" COMMAND DOES NOT AFFECT THE MSC UNLESS THE MSC IS WAITING FOR A START SIGNAL, IN WHICH CASE THE MSC WILL WAIT INDEFINITELY (UNTIL THE "GO" COMMAND IS ENTERED).

The INITIALIZATION routine proceeds as follows:

1. As soon as it is reset, the computer checks the position of the automatic wafer handling module MANUAL/AUTOMATIC toggle switch. If the switch is in the MANUAL position, the computer PAUSES until further operator commands are received via the keyboard. If the switch is in the AUTO position, the sequence continues:

2. The computer pauses for about five (5) seconds. A "CL" command at this time will halt the routine before ANY mechanical motion takes place (a "CL" command later in the sequence will halt motion following completion of any single mechanical motion which happens to be in progress). In either case, entering the "GO" command will resume the process.

3. After the five (5) second delay The computer sends commands to place the PICK AND PLACE components -- arms,claws, elevators -- in position to begin loading a batch of wafers from the SEND cassette, and unloading wafers (if any) from the pallet.

4. The computer sends a command to INDEX the pallet in the load lock.

5. The computer PAUSES until a START/CYCLE START command is received from the MSC.

7.3.3 The CRT Display

Figure 7-3 shows a typical CRT display during a wafer handling routine. Notice that the screen is divided into seven (7) distinct areas, each of which contains a different type of information. Note also that one of the areas is used to display information related to three (3) different operations: wafer handling, pallet HOME position indexing, and process gas flow levels -- according to which operation is in progress.

7.3.4 Entering Commands

The COMMAND LINE is the top line in the upper-right area of the screen. A cursor arrow shows where the operator's typed command will appear on the screen. As soon as the command is entered by depressing the RETURN key, the command line is cleared. Below the COMMAND LINE is the REPLY LINE, where the computer answers a legal operator command with the legend "TASK SCHEDULED." Illegal operator commands are answered with the query "WHAT?" The line below the REPLY LINE is called the ECHO LINE. It displays the last command

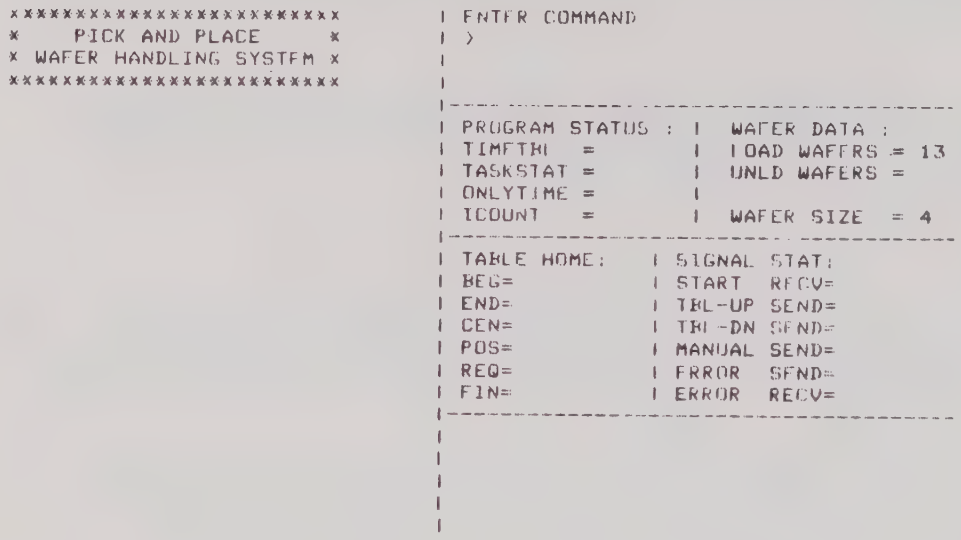


FIGURE 7-4

PE-6100 DATA TERMINAL DISPLAY (SIMULATED)

NOTE THAT THE FIELD FORMERLY DEVOTED TO GAS FLOW DATA (FIGURE 5-16) AND WAFER HANDLING DATA (FIGURE 7-3), IS NOW DEVOTED TO "TABLE HOME" DATA (FOR POSITIONING PALLET IN LOAD LOCK). EACH OF THE THREE VERSIONS IS DISPLAYED AS NECESSARY DURING OPERATION.

entered.

NOTE

For use primarily as a de-bugging tool, the PICK AND PLACE computer will accept commands other than the ones listed below. Any character string GREATER THAN two characters in length will be interpretted as a command to be sent to the MSC (except for the PICK AND PLACE commands WFLD=nn and Size=n, discussed above).

As it is typed, the command appears in the COMMAND ENTRY field (see Figure 7-3), disappears, and appears in the ECHO field. If the command is interpretted as a MSC command, the message "MSC COMMAND EXECUTED" appears in the REPLY TO COMMAND field.

If the command is NOT a valid MSC command, the error message "ILLEGAL MSC COMMAND" appears in the ERROR MESSAGE field.

Valid Commands are:

PP	Initiate PICK AND PLACE sequence
TP	Check PICK AND PLACE position
MI	Manual Mode initialization
AI	Automatic Mode initialization
AW	Automatic Mode wafer swap
AS	Automatic Mode sequence
CB	Clear wafers from wafer tracks (belts)
RC	Replace RECEIVE cassette
SC	Remove SEND cassette
CY	Cycle wafer handling system using MSC commands
GO	Run in Automatic Mode
CL	Clear all commands for manual command execution (The PICK AND PLACE will cease all automatic activity)
GD	Display Gas Flow in field alternately used to display PICK AND PLACE command mnemonics.
OC	Open claw
CC	Close claw
RA	Raise arm
LA	Lower arm

LD	Move arm to LOAD position
UN	Move arm to UNLOAD position
PK	Move arm to PARK position
SW	SEND a wafer
RW	RECEIVE a wafer
TU	Table UP
TD	Table DOWN
SU	SEND elevator UP
FS	Find a wafer to SEND
RU	RECEIVE elevator UP
FR	Find slot to RECEIVE a wafer
SI	Index SEND elevator DOWN
RI	Index RECEIVE elevator DOWN
+1	Index table clockwise one wafer position
+T	Rotate table clockwise
-1	Index table counter clockwise one wafer position
-T	Rotate table counter clockwise
ST	Stop table rotation
HM	HOME the pallet
SF	Put PICK AND PLACE in "Safe" state
RB	Index RECEIVE elevator UP
BD	Both cassette elevators DOWN
U+	Table UP signal to MSC ON
U-	Table UP signal to MSC OFF
D+	Table DOWN signal to MSC ON
D-	Table DOWN signal to MSC OFF
M+	Manual signal to MSC ON
M-	Manual signal to MSC OFF
E+	Error signal to MSC ON

E-	Error signal to MSC OFF
SM	Enter to SYSTEM MONITOR MODE (allowing access to system commands by QUALIFIED SERVICE PERSONNEL ONLY)
PM	Enter PROGRAM MODE (allows programming process instructions without data cards -- see Section 7.4, below)
SIZE=n	Enter one-digit wafer size in inches (4 or 5)
WFLD=nn	Enter number of wafers to load (00, 01, 02,...,13)

NOTE

Each command must be followed by a carriage return (i.e., RETURN). Command execution and display of command on the ECHO LINE are not always immediate.

7.3.5 Error Messages

The wafer handling system computer generates PLAIN ENGLISH error messages when an operation cannot be performed properly. For instance, if the operator instructs the PICK AND PLACE to move to the PARK position (command PK) while a cassette on the SEND elevator blocks the path of the PICK AND PLACE arm, the CRT screen of the PE-6100 data terminal will display the message "PLEASE REMOVE THE SEND CASSETTE" and an audible alarm will sound. The alarm will be silenced as soon as the condition causing the error is rectified.

More detailed error handling procedures are given in Chapter 10.

7.4 Programming the MSC via the PE-6100 Data Terminal

Model 4480 Only

From the data terminal keyboard, enter the command "PM." The data terminal screen will display a different format, called the Program Mode screen (see Figure 7-5).

The cursor will automatically move from field to field as information is typed in by the operator. If a parameter (i.e., gas pressure) is not being used, null it with "00."

Process instructions entered via the data terminal will function just like those entered via data cards, and remain stored in memory until another set of process instructions is entered, or until the computer is powered down. (Process instructions programmed on data cards have the advantage of being quicker to reload following a computer power-down.)

Chapter 8

AUTOMATIC OPERATION

All 4400-Series Production Sputtering Systems are designed to perform a number of function sequences automatically (each automated function may be performed manually, at the operator's option). Not all systems offer the same degree of automation, however. Table 8-1 compares the three systems in the 4400 Series in terms of automated functions.

This chapter describes those functions which may be controlled in the automatic mode, from the Main System controller.

TABLE 8-1

COLUMN "A" INDICATES ONE OF THE FOLLOWING:

- OPT - AN OPTIONAL CONTROLLER FOR THE SPECIFIC FUNCTION INTERFACES WITH THE MSC.
- MSC - THE MSC ITSELF PROVIDES THE SPECIFIC FUNCTION.
- P&P - THE PICK AND PLACE COMPUTER FOR THE SPECIFIC FUNCTION INTERFACES WITH THE MSC.
- N - THE SPECIFIC FUNCTION CANNOT BE CONTROLLED VIA THE MSC.

COLUMN "B" INDICATES EITHER:

- Y (YES) THE MSC CONTROLS THE SPECIFIC FUNCTION IN THE AUTOMATIC MODE.
- N (NO) THE MSC DOES NOT CONTROL THE SPECIFIC FUNCTION IN THE AUTOMATIC MODE.

FUNCTION	MODEL 4400		MODEL 4450		MODEL 4480	
	A	B	A	B	A	B
GAS FLOW	OPT	Y	OPT	Y	OPT	Y
PRESSURE CONTROL	OPT	Y	OPT	Y	OPT	Y
PUMP DOWN CONTROL	MSC	Y	MSC	Y	MSC	Y
LOAD LOCK CONTROL	MSC	Y	MSC	Y	MSC	Y
TARGET SELECTION	N	N	MSC	Y	MSC	Y
DEPOSITION VOLTAGE/POWER	CTL	Y	CTL	Y	CTL	Y
ETCH VOLTAGE/POWER	CTL	Y	CTL	Y	CTL	Y
DEPOSITION/ETCH TIME	MSC	Y	MSC	Y	MSC	Y
PALLET LOAD/UNLOAD CONTROL	MSC	Y	MSC	Y	MSC	Y
PROCESS MODE SELECTION	N	N	MSC	Y	MSC	Y
AUTOMATIC WAFER HANDLING	N/A		N/A		P&P	Y

There are two ways of controlling the system in the AUTO mode: PUSHBUTTON AUTOMATIC and PROGRAMMED AUTOMATIC.

8.1 System Functions: PUSHBUTTON AUTOMATIC

Single-function automatic routines may be initiated with a single command entered by simultaneously depressing the START pushbutton and the pushbutton controlling one of the following functions:

PUSHBUTTON	FUNCTION
PAUSE	Temporarily halts the process, until the START/CYCLE START command is given -- see Chapter 6. (If the pallet is being transferred to/from the load lock when the PAUSE command is given, the process will halt after motion stops.)
CYCLE START	Starts a programmed sequence, if one has been entered, or on systems equipped with automatic wafer handling, starts the PICK AND PLACE routine (if the PICK AND PLACE controller is switched to the AUTOMATIC position -- see Chapter 7).
STANDBY	EITHER causes the load lock to pump to vacuum OR causes the substrate pallet to be held under vacuum in the process chamber prior to processing OR causes the finished product to be held under vacuum in the load lock, depending at which point in the process the STANDBY command is given -- see Chapter 6.
UNLOAD	Causes the pallet to be unloaded from the process chamber into the load lock, and WILL ABORT A SPUTTERING OR ETCHING OPERATION IN PROGRESS -- see Chapter 6.
PUMP	Assuming the load lock and process chamber are both sealed, causes the load lock isolation valve to open if it is not already open, the mechanical pump to rough pump both the load lock and process chamber, the load lock isolation valve to close, the process chamber Hi-Vac pump to pump the process chamber to ultimate vacuum, and the load lock to vent to atmosphere -- see Chapter 6.
Vent	Causes both process chamber and load lock vent valves to open, venting the chambers to atmosphere -- see Chapter 6.
CRYO REGEN	Causes the system to perform an automatic regeneration of the optional process chamber cryogenic Hi-Vac pump, if the sputtering system is so equipped.

8.2 System Functions: PROGRAMMED AUTOMATIC

If a set of process instructions has been programmed and entered into the MSC computer via the card reader (see Chapter 6), the operator may command the system to execute the programmed routine by doing the following:

- Load substrates, either by hand (all systems -- see Chapter 9 for manual operating instructions) or using the Automatic Wafer Handling system (see Chapter 7).

- Close the load lock lid using the dual UP/DOWN rocker switches mounted on the front panel of the load lock, and the cassette chamber lid (if any) using the dual UP/DOWN rocker switches mounted on the front panel of the automatic wafer handling module.

- From the front panel of the MSC, depress the START and CYCLE START pushbuttons simultaneously.

The system will perform the programmed sequence differently for Model 4480 systems using the automatic wafer handling system (in the AUTOMATIC mode) than for systems not performing the automatic wafer handling function.

8.2.1 No Automatic Wafer Handling

The pallet is transferred into the process chamber, processed, and returned to the load lock. The load lock then vents to atmosphere, and the system enters the IDLE mode to await further instructions.

8.2.2 Wafer Handling in AUTOMATIC mode

The PICK AND PLACE mechanism unloads any wafers on the pallet into the RECEIVE cassette and loads unprocessed wafers from the SEND cassette onto the pallet. The pallet is transferred into the process chamber and processed, while the load lock is vented to atmospheric pressure with dry nitrogen. After processing, the system enters the IDLE mode, during which the pallet remains under vacuum in the process chamber. At this time, the operator may open the cassette chamber to insert, remove, or exchange cassettes, after which the cassette chamber is again closed (once closed, it is automatically pumped to vacuum).

The operator CONTINUES the automatic processing sequence by depressing the START and CYCLE START pushbuttons simultaneously, at which time the pallet is transferred from the process chamber to the load lock, and the sequence begins again (as long as there is at least one (1) wafer in the SEND cassette).

Chapter 9

MANUAL AND SEMI-MANUAL OPERATION FOR SERVICE PERSONNEL

CAUTION

IN THE MANUAL KEY SWITCH POSITION, THE SAFETY INTERLOCK FEATURES OF THE MAIN SYSTEM CONTROLLER ARE DISABLED, ALLOWING THE OPERATOR TO CONTROL FUNCTIONS THAT MIGHT, IF MIS-APPLIED, CAUSE DAMAGE TO THE SYSTEM OR TO WORK IN PROCESS. USE OF THE MAIN SYSTEM CONTROLLER IN THE MANUAL MODE MUST BE RESTRICTED TO PERSONS FAMILIAR WITH ALL ASPECTS OF SYSTEM OPERATION.

THE MANUFACTURER RECOMMENDS THAT THE MANUAL MODE BE USED ONLY FOR SERVICE OPERATIONS WHICH CANNOT BE PERFORMED WITH AUTOMATIC FUNCTIONS (I.E., CHECKING MECHANICAL MOTION WITH THE SYSTEM OPEN).

9.1 Emergency STOP Procedure

The large, red EMERGENCY button mounted on the front surface of the sputtering system, in front of and below the sputtering module, has the following function:

DEPRESSING THE EMERGENCY BUTTON IMMEDIATELY CLOSES ALL GATE VALVES AND TURNS THE MAIN SYSTEM CIRCUIT BREAKER OFF. EVERY COMPONENT IN THE SYSTEM IS TURNED OFF, INCLUDING THE RF GENERATOR(S), DC POWER SUPPLY(IES), AND ALL PUMPS.

To RESET the system, following an emergency stop, place the main circuit breaker, located in the wall-mounted circuit breaker box, in the upper, ON position.

CAUTION

IF THE SYSTEM IS LEFT IN THE POWER-DOWN MODE FOR LONGER THAN FIVE (5) MINUTES, THE PROCESS CHAMBER CRYO PUMP (IF ANY) WILL HAVE TO BE REGENERATED. CRYO PUMP REGENERATION TAKES ABOUT FOUR (4) HOURS.

9.2 Selecting the Manual Mode

NOTE

Switching the Main System Controller to the MANUAL mode requires that the operator depress and hold in the START button while turning the key switch to the MANUAL position. Both the START button and the key switch are located on the front panel of the Main System Controller.

Manual functions can be linked together by an operator or service person to produce mechanical motion, pumping, venting, sputtering, or etching. All functions possible using the automatic mode of the Main System Controller may also be controlled manually, at the operator's option.

There are two classes of manual functions controlled by the Main System Controller:

1. Pumping/Venting Functions

2. Mechanical Motion Functions

9.2.1 Status Indicator Lights

When a manual command has been executed, an LED indicator on the front panel of the Main System Controller will be turned ON or OFF to show that the function has been accomplished. The LED indicators report changes in system status as reported by sensors located throughout the system. One function, pallet location, is NOT verified by sensors, but is tracked by software. It is possible, therefore, to send the carriage into the process chamber without a pallet, and have the PALLET IN PROCESS CHAMBER indicator light.

9.3 Outline of Manual Procedures

9.4 PUMPING AND VENTING
- 9.4.1 SYSTEM START-UP
- 9.4.2 VENTING THE LOAD LOCK
- 9.4.3 VENTING THE LOAD LOCK AND PROCESS CHAMBER
- 9.4.4 PUMPING THE SYSTEM TO HI-VAC

9.5 MECHANICAL MOTION
- 9.5.1 LOADING A PALLET INTO THE PROCESS CHAMBER
- 9.5.2 RF AND DC OPERATION

9.6 MANUAL WAFER LOADING

9.4 Pumping and Venting Functions

Pumping and Venting functions (i.e., process hi-vac pump ON/OFF, process chamber vent valve OPEN/CLOSED, load lock isolation valve OPEN/CLOSED) are initiated via two (2) position toggle switches located on the front panel of the Main System Controller. In each case, the upper position is labeled with one function (e.g., UP), and the lower position produces the opposite motion (e.g., DOWN).

9.4.1 System Start-Up

1. Place ALL 2-Position Main System Controller (MSC) toggle switches in the DOWN position.

2. Place ALL 3-Position MSC toggle switches in the MIDDLE position.

3. Turn (MSC) key switch to the MANUAL position.

4. At utility panel (center back of system, at floor level - see Figure 9-1), turn 115 VAC circuit breaker ON; turn 24 VAC circuit breaker ON; turn circuit breakers for all pumps ON. (System is now powered up with MSC disabled.)

5. At utility panel, turn cold water ON (check that paddle wheels on water flow switches are turning).

6. Check that process chamber is closed (i.e., that sputtering module is not raised).

7. Check that load lock lid is closed (on Model 4480 systems, check that cassette chamber lid is also closed).

8. Turn MSC key switch to the PROGRAM position.

9. On the MSC, depress and hold IN the START button while turning the key switch to the MANUAL position. (MSC is now enabled for manual operation.)

10. On the MSC, place the LOCK toggle switch in the upper, OPEN, position.

11. On the MSC, place the LOCK ROUGH VALVE toggle switch in the upper, OPEN, position.

12. IF SYSTEM INCLUDES AN OPTIONAL TURBOMOLECULAR LOAD LOCK PUMP, from the MSC, place the 2nd toggle switch from the left, MECH PUMP (roughing the load lock turbo pump) in the upper, ON, position.

13. On the MSC, place the 6th toggle switch from the left, MECH PUMP (roughing the load lock and process chamber) in the upper, ON, position.

14. On the MSC, check that both the LOCK PRESSURE and CHAMBER PRESSURE gauges indicate identical increasing vacuum levels (if gauges do not give identical readings, LOCK isolation valve may not be OPEN; check LOCK toggle switch position).

15. When gauges indicate a vacuum level of 150 milliTorr, from the MSC, place the LOCK ROUGH VALVE toggle switch in the lower, CLOSE, position.

16. On the MSC, place the LOCK toggle switch in the lower, CLOSE, position.

17. IF SYSTEM HI-VAC PUMP IS TURBOMOLECULAR, from the MSC, place the FORELINE VALVE toggle switch in the upper, OPEN, position.

18. On the MSC, place the 11th toggle switch from the left, HV PUMP, in the upper, ON, position.

19. Wait until the speed indicator on the process chamber turbo pump frequency controller indicates that the pump is at speed (typically five (5) minutes).

20. On the MSC, place the 12th toggle switch from the left, GATE VALVE (process chamber), in the upper, OPEN, position.

21. IF SYSTEM INCLUDES AN OPTIONAL TURBOMOLECULAR LOAD LOCK PUMP, from the MSC, place the 3rd toggle switch from the left, TURBO PUMP, in the upper, ON, position.

22. IF SYSTEM INCLUDES AN OPTIONAL TURBOMOLECULAR LOAD LOCK PUMP, wait until the speed indicator on the load lock turbo pump frequency controller indicates that the pump is at speed (typically five (5) minutes).

23. IF SYSTEM INCLUDES AN OPTIONAL TURBOMOLECULAR LOAD LOCK PUMP, from the MSC, place the 4th toggle switch from the left, GATE VALVE (load lock), in the upper, OPEN position.

24. CHECK THAT VACUUM LEVEL IN PROCESS CHAMBER REACHES 1×10^{-7} Torr (cryo pump) or 3×10^{-7} Torr (turbo pump).

9.4.2 Venting the Load Lock

WITH THE MSC KEY SWITCH IN THE MANUAL POSITION

1. IF SYSTEM IS EQUIPPED WITH AN OPTIONAL LOAD LOCK TURBOMOLECULAR PUMP, from the MSC, place the 4th toggle switch from the left, GATE VALVE (load lock) in the lower, CLOSE, position. (NOTE: PROCESS AND LOAD LOCK GATE VALVES ARE NEVER OPENED SIMULTANEOUSLY.)

2. From the MSC, place the LOCK toggle switch in the lower, CLOSE, position.

3. From the MSC, place the LOCK VENT toggle switch in the upper, OPEN

position. The load lock will vent to atmosphere.

WITH THE MSC KEY SWITCH IN THE AUTO POSITION

In the AUTO mode (systems without automatic wafer handling, or on Model 4480 systems when the automatic wafer handling system is switched to the MANUAL mode), the load lock is NORMALLY in the vented condition, unless the there is work in process OR the system was placed in the STANDBY mode (see Chapter 6). If either of the above conditions exists, simultaneously depressing the START and UNLOAD pushbuttons will initiate an automatic unload sequence, as part of which the load lock is vented.

9.4.3 Venting the Load Lock and Process Chamber

WITH THE MSC KEY SWITCH IN THE MANUAL POSITION

1. IF SYSTEM IS EQUIPPED WITH AN OPTIONAL LOAD LOCK TURBOMOLECULAR PUMP, from the MSC, place the 4th toggle switch from the left, GATE VALVE (load lock) in the lower, CLOSE, position.

2. From the MSC, place the 7th toggle switch from the left, LOCK ROUGH VALVE, in the lower, CLOSE, position.

3. From the MSC, place the LOCK toggle switch in the upper, OPEN, position.

4. From the MSC, place the 12th toggle switch from the left, GATE VALVE (process chamber) in the lower, CLOSE, position.

5. From the MSC, place the LOCK VENT toggle switch in the upper, OPEN position. The load lock will vent to atmosphere.

6. From the MSC, place the CHAMBER VENT toggle switch in the upper, OPEN, position.

WITH THE MSC KEY SWITCH IN THE AUTO POSITION

Simultaneously depress the START and VENT pushbuttons.

9.4.4 Pumping a Vented System to Hi-Vac

Assuming the system is operating normally, and has been vented to atmosphere without venting the cryogenic pump (if any):

1. Check that all vent valves and chamber lids are closed.

2. Place the MSC key switch in the AUTO position.

3. Simultaneously depress the START and PUMP pushbuttons.

9.5 Mechanical Motion Functions

Mechanical Motion Functions (e.g, elevator UP/DOWN, carriage IN/OUT, table UP/DOWN) are initiated via three (3) position toggle switches located on the front panel of the Main System Controller. In each case, the upper position is labeled with one function (e.g., UP), the lower position produces the opposite motion (e.g., DOWN), and the middle position STOPS motion. After a switch has been moved to either the upper or lower position, there is a delay of about five seconds before motion occurs.

9.5.1 Manually Loading the Pallet into the Process Chamber

To manually transfer a pallet of wafers from the normal wafer loading position (in the load lock, elevator in the UP position):

NOTE

Before performing this operation, check that the PALLET IS OUT status indicator LED is ON. If it is not, the pallet should already be in the process chamber.

1. From the MSC, simultaneously depress and hold the START pushbutton while turning the key switch to the MANUAL position.

2. Check that the UP status indicator LED (located to the right of the PALLET IS OUT legend) is ON. If it is NOT, skip the next step.

3. From the MSC, place the ELEV toggle switch in the lower, DOWN position until the UP status indicator LED (located to the right of the PALLET IS OUT legend) goes dark and the DOWN indicator LED lights; then place the ELEV toggle switch in the middle, OFF, position.

4. From the MSC, place the LOCK toggle switch in the upper, OPEN, position.

5. If the UP status indicator LED (located to the right of the PALLET IS IN legend) is OFF, and the DOWN indicator LED is ON, skip the next step.

6. From the MSC, place the TABLE toggle switch in the lower, DOWN position, until the UP indicator LED goes dark and the DOWN indicator LED lights; then place the TABLE toggle switch in the middle, OFF, position.

7. From the MSC, place the CARR toggle switch in the upper, IN, position until the PALLET IS OUT indicator LED goes dark and the PALLET IS IN indicator LED lights; then place the CARR toggle switch in the middle, OFF, position. (There will be an audible noise as the carriage reaches the end of its travel against the process chamber wall.)

8. From the MSC, place the TABLE toggle switch in the upper, UP position

until the DOWN status indicator LED (located to the right of the PALLET IS IN legend) goes dark and the UP indicator LED lights; then place the TABLE toggle switch in the middle, OFF, position.

9. From the MSC, place the CARR toggle switch in the lower, OUT, position until the PALLET IS IN indicator LED goes dark and the PALLET IS OUT indicator LED lights; then place the CARR toggle switch in the middle, OFF position.

10. From the MSC, place the LOCK toggle switch in the lower, CLOSE, position.

The pallet is now in the process chamber in the proper position for SPUTTER DEPOSITION (i.e., table UP.) If the pallet is to be placed in the proper position for ETCHING, from the MSC, place the TABLE toggle switch in the lower, DOWN position until the UP status indicator LED (located to the right of the PALLET IS IN legend) goes dark and the DOWN indicator LED lights; the place the TABLE toggle switch in the middle, OFF position.

CAUTION

DO NOT ATTEMPT TO MOVE THE CARRIAGE IN WITH THE PALLET ON THE TABLE AND THE TABLE IN THE DOWN POSITION, OR DAMAGE TO THE SYSTEM MAY OCCUR.

9.6 Manual Wafer Loading

Models 4400/4450 are not equipped with the automatic wafer handling system, and must be loaded manually. The Model 4480 is equipped for automatic wafer loading from cassettes, but may be loaded manually if desired (useful if substrates other than 4" (100mm) or 5" (125mm) wafers are to be processed.

The wafer loading procedure differs between Models 4400/4450 and Model 4480.

The wafer loading procedure described below assumes that the operator uses two identical pallets, removing and replacing wafers on one while the other is being processed.

9.6.1 Models 4400/4450

1. With the pallet in the load lock, raise the load lock lid by simultaneously moving the twin load lock lid UP/DOWN rocker switches to the UP position and holding them until the lid is fully raised. (The load lock elevator will automatically raise the pallet almost level with the rim of the load lock.)

2. Grasp the pallet with the special tool provided and lift clear of the load lock. Place pallet on a suitable flat surface.

3. Grasp the second pallet (on which new wafers have been arranged previously) with the tool and replace in the load lock.

4. Close the load lock lid (both UP/DOWN rocker switches in the lower position until the lid is sealed).

5. From the MSC, simultaneously depress the START and CYCLE START pushbuttons to start the programmed sequence (if using a programmed sequence -- otherwise, proceed to control the process manually, as described earlier in this chapter).

6. While the pallet of new wafers is being processed, remove the already-processed wafers (using wafer tweezers) and place them in appropriate container(s).

7. If there are more wafers to be processed, place them on the empty pallet using wafer tweezers.

8. Repeat as necessary.

NOTE

It is also possible to remove processed wafers and replace them with new wafers WITH THE PALLET IN THE LOAD LOCK.

9.6.2 Model 4480

1. From the front panel of the automatic wafer handling module, place the AUTOMATIC/MANUAL rocker switch in the MANUAL position.

2. With the pallet in the load lock, raise the load lock lid by simultaneously moving the twin load lock lid UP/DOWN rocker switches to the UP position and holding them until the lid is fully raised. (The load lock elevator will NOT raise the pallet, so it will be necessary to reach down into the load lock to lift out the pallet.)

3. Grasp the pallet with the special tool provided and lift clear of the load lock. Place pallet on a suitable flat surface.

4. Grasp the second pallet (on which new wafers have been arranged previously) with the tool and replace in the load lock.

5. Close the load lock lid (both UP/DOWN rocker switches in the lower position until the lid is sealed).

6. From the MSC, simultaneously depress the START and CYCLE START pushbuttons to start the programmed sequence (if using a programmed sequence -- otherwise, proceed to control the process manually, as described earlier in this chapter).

7. While the pallet of new wafers is being processed, remove the already-processed wafers (using wafer tweezers) and place them in appropriate container(s).

8. If there are more wafers to be processed, place them on the empty pallet using wafer tweezers.

9. Repeat as necessary.

NOTE

When using the Model 4480 in the manual wafer handling mode, (using the pallet designed for automatic wafer loading) it is typical to load and unload wafers WITH THE PALLET IN THE LOAD LOCK.

9.7 Manual RF and DC Operation

9.7.1 RF Operation

WITH RF STABILIZER ON

1. Check that RF generator circuit breaker is ON.
2. Check that process chamber vacuum level is better than 10 milliTorr.
3. For Models 4450/4480, check that the SEQUENCE rocker switch, located on the sputtering module front panel, is in the MANUAL position.
4. From the RF stabilizer front panel, turn the RF stabilizer ON.
5. From the RF stabilizer front panel, place the VOLTAGE/POWER rocker switch in either the VOLTAGE or POWER position (to determine if the unit will vary power to stabilize VOLTAGE, or vary voltage to stabilize POWER.
6. Depress the RF ON pushbutton, located on the sputtering module front panel.
7. While reading FORWARD POWER from either the digital display located on the RF stabilizer front panel or the analog meter located on the sputtering module front panel, turn the potentiometer on the RF stabilizer front panel until the desired forward power level is reached. (Turning the pot to the right increases power; turning the pot to the left decreases power.)

WITH RF STABILIZER OFF

1. Check that RF generator circuit breaker is ON.
2. Check that process chamber vacuum level is better than 10 milliTorr.
3. For Models 4450/4480, check that the SEQUENCE rocker switch, located on the sputtering module front panel, is in the MANUAL position.
4. From the RF stabilizer front panel, turn the RF stabilizer OFF.
5. From the RF stabilizer front panel, place the VOLTAGE/POWER rocker switch in either the VOLTAGE or POWER position (to determine if the unit will vary power to stabilize VOLTAGE, or vary voltage to stabilize POWER.
6. Depress the RF ON pushbutton, located on the sputtering module front panel.

7. While reading FORWARD POWER from either the digital display located on the RF stabilizer front panel or the analog meter located on the sputtering module front panel, turn the precision potentiometer on the sputtering module, front panel until the desired forward power level is reached. (Turning the pot to the right increases power; turning the pot to the left decreases power.)

9.7.2 DC Operation

1. DC POWER SUPPLY IN UNTIMED MODE

2. Check that process chamber vacuum level is better than 10 milliTorr.

3. From the DC magnetron controller, place the MANUAL/PROGRAM rocker switch in the MANUAL position.

4. From the DC magnetron controller, momentarily depress the CONT. pushbutton (button will light after being depressed).

5. While reading DC power from the KILOWATTS digital display, located on the DC magnetron controller front panel, turn the POWER ADJUST potentiometer on the DC magnetron controller until the desired power level is reached.

6. To turn DC power OFF, from the DC magnetron controller, momentarily depress the STOP pushbutton (button will light after being depressed).

DC POWER SUPPLY IN TIMED MODE

1. Check that process chamber vacuum level is better than 10 milliTorr.

2. From the DC magnetron controller, place the MANUAL/PROGRAM rocker switch in the MANUAL position.

3. From the timer, located on the front panel of the DC controller, set the desired sputtering time in minutes (each time the pushbutton below a digit is depressed, that digit INCREMENTS by one).

4. From the DC magnetron controller, momentarily depress the TIMED pushbutton (button will light after being depressed).

5. While reading DC power from the KILOWATTS digital display, located on the DC magnetron controller front panel, turn the POWER ADJUST potentiometer on the DC magnetron controller until the desired power level is reached.

6. If it is necessary to turn OFF DC power before timer reaches zero, depress STOP pushbutton.

7. DC power will turn OFF automatically when the timer reaches zero.

Chapter 10

ERROR HANDLING

10.1 Routine Error Handling

The 4400-Series Production Sputtering Systems are designed to be operated primarily in the AUTOMATIC mode, in which physical and software safety interlocks protect the system from misuse. In the AUTOMATIC mode, the system is largely self-diagnosing. If the operator makes an error, like asking the automatic wafer handling system on a Model 4480 to move the PICK AND PLACE arm to the PARK position while the SEND cassette is in the way (i.e., on the SEND elevator) an audible alarm will sound; the system will halt all motion and display on the PE-550 data terminal CRT screen a PLAIN ENGLISH MESSAGE telling the operator what is wrong. In the case described above, the message would read "REMOVE SEND CASSETTE."

Other operator errors are treated in a similar fashion. For example, running a programmed sequence on a Model 4450 or 4480 with the sputtering module sequence switch in the MANUAL position will cause an error message to be displayed as follows: "SWITCH IN MANUAL POSITION."

The error message and audible alarm will be cleared as soon as the error is corrected (the audible alarm on the MSC may be silenced immediately by momentarily depressing the SILENCE button mounted on the front panel of the MSC).

10.2 More Serious System Faults

If the error cannot be cleared simply by changing a switch setting, changing a wafer cassette, clearing away jammed wafers, seating a cassette properly on its elevator, etc., the problem must be referred to a service technician. DO NOT ATTEMPT TO SERVICE THE SYSTEM YOURSELF.

It may be possible to continue production operations while awaiting the service person, depending on which subsystem is affected. For instance, if the automatic wafer handling system is defective, it is a simple matter to switch the automatic wafer handling module from AUTOMATIC to MANUAL, and load wafers manually (see Chapter 9 for manual wafer loading instructions). A failure of the Brooks automatic gas flow controller(s) can be bypassed by placing the appropriate manual gas flow ON/OFF toggle valve(s) in the ON position, adjusting the appropriate needle valve(s) for the desired flow rate, and running the automatic process just as if the Brooks system were operational.

The following process parameters CANNOT be controlled manually while running an automatic process:

- Target Selection (Models 4450/4480)
- Process Mode Selection (Models 4450/4480)

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